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BIOMEDICAL AND BEHAVIORAL SCIENCES

No. 28

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BIOCHEMISTRY

UDC 617-089-03:615.35

SURGICAL APPLICATION OF IMMOBILIZED PROTEOLYTIC ENZYMES AND THEIR INHIBITORS

Leningrad VESTNIK KHIRURGII IMENI I. I. GREKOVA in Russian Vol 129, No 9, Sep 82 (manuscript received 20 Jul 81) pp 89-92

[Article by V. K. Gostishchev, Z. F. Vasil'kova, G. S. Vavilova, V. G. Vladimirov, A. D. Virnik and N. I. Larionova, Department of General Surgery (headed by Academician, USSR Academy of Medical Sciences V. I. Struchkov), First Moscow Medical Institute imeni I. M. Sechenov]

[Text] Among the vast quantity of pharmacological agents used to treat inflammatory diseases, proteolytic enzymes of animal and bacterial origin and their inhibitors have gained the widest recognition and use. However, the insufficient stability of proteinases, their potential inactivation by inhibitors in the blood and tissues, rapid excretion from the body and, in addition, their antigenicity and expense, to a great extent limit their practical application.

Immobilized trypsin, chymotrypsin, the bacterial-enzyme preparation terrilitin and kininogenase inhibitor were prepared at the Department of Chemical Enzymology, Moscow State University, and the Department of Chemical-Fibers Technology, Moscow Textile Institute, jointly with the Department of General Surgery, First Moscow Medical Institute imeni I. M. Sechenov [1-3].

The immobilized-enzyme preparations were studied in the form of soluble films and drainage compositions. The quantity of enzyme incorporated into a composition was from 1% to 5%. Immobilized-enzyme preparations on a soluble base were applied in the form of films, placed on the wound surface daily. Drainage compositions based on an insoluble polymer were inserted into the wound after opening the abscess and remained in the wound for 3 to 14 days.

Experiments were conducted on 120 rabbits to study the effect of immobilized proteolytic enzymes on the healing rate of purulent wounds.

The model investigated comprised a wound formed in the interscapular region by means of removal of a skin flap of 600 mm^2 area together with the subcutaneous fat down to the muscle layer, with crushing of the underlying muscles and wound margins. Then a standard culture of pathogenic

Staphylococcus albus (strain 75) was introduced into the wound. A purulent inflammation developed in the wound after 48 hours. Treatment of the animals was begun at this time.

The time in which the wound was cleared of pus was much shorter when trypsin immobilized in the film structure of a water-soluble or water-insoluble polymer was used to treat purulent wounds than when native trypsin was applied locally (6 and 4 days, respectively). Especially effective was the use of proteinases immobilized in the film structure of a water-soluble polymer. It should also be noted that when immobilized preparations were used the quantity of enzyme introduced daily into the wound was six- to seven-fold less than the quantity used during treatment with native preparations of the same enzymes.

The use of immobilized enzymes in the form of soluble films greatly intensified the reparative processes in the wounds. Thus, as early as the fifth day the wound was filled with a granular tissue, within which numerous fibrobalsts with an RNA-positive cytoplasm and, also, vertical vascular elements were visible. Organized argyrophil and fuchsinophil collagenous fibrils were situated near the fibroblasts. Considerable epithelial growth was noted on the surface of the granular tissue. The reparative processes in the wound were more pronounced on the 10-15th day compared with the control. The granular tissue was tranformed into a fibrocicatricial tissue, the wound defect epithelized over a much larger extent and the total quantity of neutrophilic leucocytes and macrophages declined. Inflammatory infiltration in the tissues surrounding the wound was less pronounced than in animals of the control group, where even on the 15th day after the operation, although there was a negligible further granular-tissue maturation, secondary necrotic changes in the fibrous layer and the underlying tissues intensified and the further formation of microabscesses occurred.

Thus, the stimulatory influence of enzymes immobilized in the form of soluble films was expressed as a reduction of the healing time of purulent musculocutaneous wounds. The effect was apparently due to the prolonged action of the proteinases on the tissues, which was accompanied by an active process of necrolysis, a considerable decline in infectiousness and wound inflammatory changes and, also, an acceleration of granular-tissue formation and maturation and cicatrix epithelization.

When an immobilized-proteinase preparation on an insoluble base was employed, the course of the wound process in the experimental animals was expressed as a change in the phasic nature of the wound process (hydration phase) and, as a result of this, in a reduction in the wound healing time. The time for wound necrolysis was 8.3±0.6 days in the main animal group and 29.6±4.7 days in the control group; the wound healing times were 25.4±3.12 and 36.1±5.2 days, respectively.

A pronounced stimulation of the healing of infected musculocutaneous wounds, which was expressed in an active necrolysis, a decline in bacterial dissemination and, also, in an acceleration of reparative-regeneration processes, was noted under the influence of a drainage composition based on an insoluble polymer containing enzymes of both animal and bacterial origin. Evidently, prolonged enzyme action greatly accelerated wound clearing, which shortened the stage of traumatic and microbial inflammation and, as a result, promoted an earlier development of the proliferative stage and the stage of formation and reorganization of a connective-tissue cicatrix.

Experience from the use of immobilized proteinases in clinical practice during the treatment of various purulent-inflammatory diseases of soft tissues, bones and trophic ulcers in 115 patients demonstrated their higher effectiveness compared with the common, traditional treatment methods and the treatment method using native enzyme preparations.

The changes demonstrated in the course of the wound process and in reparative regeneration under enzymotherapeutic conditions were indentical using both native and immobilized enzyme preparations; the differences bore only a quantitative character. The processes of necrosis and abatement of the inflammatory response occurred more rapidly under the influence of immobilized enzymes. In comparing the character of the morphological and histochemical changes observed under enzymotherapeutic conditions with those observed during the natural course of the inflammatory process, of interest was the fact that the character of the changes did not go beyond the scope of the common course of the process, i. e., enzymotherapy with immobilized proteinases had a pathogenetic directionality and sufficient pathophysiological bases. The gradual release of small doses of proteolytic enzyme from the surface of the composition increased its drainage capacity, accelerated wound clearing and healing and made it possible to use drainage material without replacement for an extended time (up to 2 weeks), which in its turn eliminated the destruction of the granular tissue which occurs during frequent changes of the common drainage material and reduces by several fold the expenditure of expensive enzyme preparations.

Under contemporary conditions, implantational infection is frequently cause of postoperative purulent-inflammatory complications. If we are to speak of the comprehensive prophylaxis of wound infection and its control at the routes of its transmission, it is impossible to ignore the role of suture material in the development of inflammatory complications of operative and infected wounds subjected to primary surgical treatment. The data obtained in our clinic and published data made it possible to establish the presence of an inflammatory tissue response to sutural ligatures independently of the type and character of the material (acetate, silk and capron threads). Necrotic regions, leucocytic infiltration and hemorrhages appeared around the threads. After 2-3 weeks the ligatures were isolated following the pattern of foreign bodies. This process always occurs if it develops under aseptic conditions, but the virulence of the flora is intensified by 1,000-fold in the presence of a ligature under conditions of aseptic inflammation; thus, no less than one million microbial bodies must be introduced into the tissues to form a purulent inflammation, while 100 cocci are sufficient in the presence of a ligature. Contemporary polyphilic nonabsorbable suture materials support the inflammatory process in the wound and are a cause of development of purulent-inflammatory wound complications.

We studied in an animal experiment and tested in the clinic various types of suture material prepared from "phtorlon" fiber, into whose structure furazolidone (a preparation of the nitrofuranyl series) and, also, trypsin were introduced during the molding process [1-3].

The experimental investigations were conducted on 250 male guinea pigs, 150-200 g weight. The animals were divided into three groups after receiving an aseptic linear wound 5 cm long and 0.5 cm wide in the interscapular region. In the first group of animals the wound was sutured with the investigated surgical-thread samples immediately after wound inflication. In the second group, 1 ml of a Staphylococcus agar-culture suspension, standardized and diluted to 10^{12} microbial bodies per 1 ml, was applied to the wound before suturing. An Escherichia coli culture prepared in a similar manner and diluted to 10^7 microbial bodies per 1 ml was used for infection in the third group.

The tissue response to phtorlon-dacron threads containing enzyme was expressed to a lesser degree than that to phtorlon-furazolidone threads and was approximately equivalent to pure phtorlon threads. The presence in the threads of proteolytic enzymes promoted an earlier resorption of the tissue detritus and subsequent activation of the proliferative response. In fact, the inflammatory granulomas forming around the enzyme-containing thread matured and fibrosed in shorter times. Suppuration of the aseptic wounds was observed in the experiment in 12.5% when silk was used, in 4.5% when dacron and capron were used, in 4% when phtorlon was used and in 4% when phtorlon modified with trypsin was used. Deliberate wound infection with Staphylococci and E. coli to a great extent changed the course of the inflammatory response and led to the appearance of suppurations in 40-45% when silk threads were used, in 25-33% when capron threads were used, in 13-14% when threads of phtorlon with trypsin were used, in 20-25% when threads of phtorlon with dacron were used and in 7.7-8.3% when threads of phtorlon with furazolidone were used.

Of interest during the histological investigation of tissues removed from the zone of enzyme-containing sutural ligature was the less pronounced degree of the inflammatory response. Although it was not possible to demonstarte in vitro an antimicrobial action for threads with proteinases, their application was effective in vivo. Apparently, when surgical suture threads with immobilized enzymes are used, a prolonged anti-inflammatory enzymatic effect on the wound is achieved due to the gradual diffusion of the enzyme from the fibers. Therefore, even under conditions of artificially created bacterial wound contamination, the inflammatory response was less expressed and the number of wound suppurations was smaller than during the use of threads consisting of the same chemical materials.

Polyvalent proteinase inhibitor from cattle pancreas effectively inhibits kallikrein, chymotrypsin, plasmin, plasmin activator, blood clotting factors and tissue and leukocytic proteinases. Pancreatic inhibitor is used in the treatment of diseases associated with the activation of the body's kinin system. Such diseases include: acute pancreatitis, primary hyperfibrinolytic hemorrhages and consumption coagulopathy, burn disease, nephrotic syndrome and shocks of various etiology. Pancreatic inhibitor is effective during treatment of the forementioned diseases by normalizing the state of the kinin system, which is achieved by the application of large doses of expensive preparations. This is because the inhibitor is rapidly eliminated from the blood, while the half-life of pancreatic inhibitor depends upon the animal species and preparation dose and comprises 10-70 min. The need to maintain a high concentration of pancreatic inhibitor in the blood calls for a prolongation of inhibitor action.

A preparation of pancreatic inhibitor bound to a negatively charged polysaccharide matrix was used to study its organ distribution and elimination from the body. A solution of the inhibitor preparation was injected into the caudal vein of rats at a dose of 1,000 U per 100 g weight.

Comparison of the circulation time in the blood of the native pancreatic inhibitor with that of its polysacchardie derivative showed that the rate of removal of the modified inhibitor from the blood was nearly 10-fold slower than that of the native inhibitor. Acute pancreatitis was selected as a model of the pathological process for a study of the therapeutic effect of immobilized kininogenase inhibitor, and this was not by accident. A preparation of the inhibitor bound to carboxymethyldextran has been tested in the treatment of acute pancreatitis in dogs. Acute pancreatitis was reproduced by injecting an incubated mixture of bile and trypsin into the main pancreatic duct at a dose of 0.25 ml/kg animal weight. Hemorrhagic pancreatitis developed in 3 hours. Three hours after the injection of the mixture the inhibitor was infused at a dose of 5,000 U/kg weight. Blood samples were taken for analysis from the femoral vein of the animal before reproduction of pancreatitis and at 3, 24 and 72 hours after the operation. Pancreatitis developed 3 hours after the injection of bile and trypsin, and all untreated animals died. Inhibitor injection gave a positive effect; moreover, use of the high molecular weight inhibitor derivative increased the survival rate by 1.5-fold and increased the life-span of the animals that died by 2-fold. This means that the time employable for additional treatment was increased.

The preliminary data demonstrated the high effectiveness of the therapeutic agents--immobilized proteolytic enzymes and their inhibitors.

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UDC 541.143

ELECTRIC FIELD REGULATION OF BACTERIORHODOPSIN PHOTOCONVERSION CYCLE

Moscow BIOORGANICHESKAYA KHIMIYA in Russian Vol 8, No 9, Sep 82
(manuscript received 11 Mar 82 and, after revision, 29 Apr 82)
pp 1173-1179

LUKASHEV, Ye. P., VOZARI, E., KONONENKO, A. A. and RUBIN, A. B., Biological Faculty, Moscow State University imeni M. V. Lomonosov; and ABDULAYEV, N. G., Institute of Bioorganic Chemistry imeni M. M. Shemyakin, USSR Academy of Sciences, Moscow

[Abstract] Experiments conducted under conditions of blue-green illumination and darkness demonstrated that the application of an electric field (ca. 10^7 $V \cdot m^{-1}$) to air-dried films of Halobacterium halobium R_1 purple membrane retards the rate of decay of the M form of bacteriorhodopsin (BR). These observations suggest the possible existence of electric field-dependent molecular feedback mechanisms which regulate BR photoconversion. Inhibition of the conversion of the M form into native BR may depend on diminished interaction of the deprotonated schiff base with proton donor groups of the amino acids that form proton channels in BR molecules. This may be due to alterations in the dielectric properties of the environment around the retinal that affect intramolecular mobility in BR and lead to localized structural changes. Figures 5; references 12: 3 Russian, 9 Western.
[67-12172]

UDC 547.458.02:577.11

MYCOBACTERIAL POLYSACCHARIDES. PART 5. STRUCTURE OF FREE EXTRACELLULAR POLYSACCHARIDE SYNTHESIZED BY MYCOBACTERIUM SALIVARUM 76

Moscow BIOORGANICHESKAYA KHIMIYA in Russian Vol 8, No 9, Sep 82
(manuscript received 6 Apr 82) pp 1242-1250

SVIRIDOV, A. F., SHASHKOV, A. S. and KOCHETKOV, N. K., Institute of Organic Chemistry imeni N. D. Zelinskiy, USSR Academy of Sciences, Moscow; BOTVINKO, I. V. and YEGOROV, N. S., Moscow State University imeni M. V. Lomonosov

[Abstract] In order to elucidate their structural properties, extracellular polysaccharides produced by Mycobacterium salivarum 76 were subjected to chemical analysis (acid hydrolysis, methylation, periodate oxidation) and ^{13}C-NMR spectroscopy. The polysaccharide was found to contain D-mannose, D-glucose, D-glucuronic acid, and pyruvic acid in a 1:1:1:2 ratio and physicochemical properties similar to those of pectin and algin; spectroscopy demonstrated the presence of three carboxyl groups per three monosaccharide moieties. On the basis of the findings a structural formula for the extracellular polysaccharide is proposed. References 22: 6 Russian, 16 Western.
[67-12172]

BIOTECHNOLOGY

UPDATE ON INDUSTRIAL MICROBIOLOGY

Dushanbe KOMMUNIST TADZHIKISTANA in Russian 1 Sep 82 p 2

[Article by P. Solozhenkin, academician of the Tajik Academy of Sciences: "What Can Microbiology Do? Science: Problems, Research, Discoveries"]

[Text] Molecular biology and molecular genetics, physicochemical biology and biotechnology are disciplines that were recently purely theoretical, which have opened up utterly new horizons for man's practical endeavors. Formerly unavailable products, of great importance to medicine and agriculture, are being recovered microbiologically from diverse inexpensive raw materials.

The uninformed person will often relate the role of microorganisms in life to the harm that they inflict to him: in his consciousness, the word, "microbe" is associated with the word "disease." Yet the world of useful microorganisms is truly immense, and without them many technological processes would be impossible at the present time.

Various investigations are being pursued in the scientific research institutes of the Tajik Academy of Sciences and of institutions under some ministries of this republic on the use of microbiological products and preparations in nonferrous metallurgy, chemical and textile industries, agriculture.

For example, in the nonferrous metallurgical industry, attention is given to bacterial leaching. Live microorganisms circulate over the plant technological circuit and are instrumental in recovery of copper, arsenic and other metals. The microorganism that is used as a metallurgist is Thiobacillus ferrooxidans.

New "silicate," "slime" microorganisms are used for desiliconization of bauxite-like rock.

At the present time, it was demonstrated at the Institute of Chemistry, Tajik Academy of Sciences, that it is possible to transfer antimony and tin from antimony and tin concentrates to solution by means of sulfate-reducing bacteria. Antimony and tin go entirely into solution. There are several advantages to use of bacteria over the widely used sodium sulfate. Scientists have proposed flotation reagents of biological origin for processing nonsulfide ore. The results of industrial tests revealed that bacterial fat is a promising collecting agent, which makes it possible to reduce the outlay of expensive oleic acid and virtually excludes heating of flotation pulp.

Methods have been developed for broad use of sulfate-reducing bacteria as reagents in the processing of sulfide ore by the flotation method.

Microbiology plays a particularly important role in protecting farm crops against pests that destroy a considerable part of the harvest.

The Institute of Zoology and Parasitology imeni Ye. N. Pavlovskiy, Tajik Academy of Sciences, has isolated live pesticides, a bacterial and fungal strain, which are used in Tajikistan for the control of codling moth and bollworm caterpillars. It was determined that a developed product, carnecin, is very effective, and it is harmless to animals. If production of carnecin were organized in this republic it would improve the quality and efficacy of the product considerably.

Work on processing guza-paya [cotton stems and bolls] for protein feed with use of microbiological processes merits attention.

Microbial synthesis using cheap natural resources referable to organic matter and industrial waste plays an important part in solving the problem of shortage of protein. Microorganisms grow hundreds of times faster than the most productive farm crops, thousands of times faster than the most productive animals. We should like to cite some figures: a planted area of 360 ha is required to produce a ton of protein in the form of peas per day, and the same amount of protein in beef per day is obtained from fattening 2000 head of cattle. But when using microorganisms, the same amount of protein can be recovered from 10 kg yeast cells in a fermenter with working capacity of 100 cubic meters.

If we consider the fact that microorganisms are not demanding with regard to nutrition, the advantages of using them to recover protein and other biological components are obvious.

In recent times, along with use of hydrocarbons of petroleum and gas, efforts are being made to use various cellulose-containing agricultural waste for production of protein feed--straw, leaves and stems of various plants, guza-paya.

Microscopic fungi synthesize a wide assortment of enzymes, which enables them to convert agricultural waste into edible protein with use of various carbon-containing substrates.

Uzbekistan scientists have proposed the use of the fungus, Trichoderma lignorum 19, for enzymatic processing of guza-paya and use thereof as cattle and sheep feed.

Cultivation of microscopic fungi on cellulose-containing waste will largely solve both the protein problem and that of utilizing agricultural waste.

Wilt, which is a disease caused by a microscopic soil fungus, inflicts much detriment to modern cotton growing. Until recently, biology and genetics of this microorganism had been little-studied, and this made it difficult to develop effective measures to control it. Research conducted in the Department of General Genetics of the Cotton Plant of the Tajik Academy of Sciences revealed that the pathogen of wilt (Verticillium) is represented by several physiological races in the cotton-growing region.

Assemblage of genetic collections of microorganisms is very important to theoretical work with various microorganisms, including phytopathogens. A well-studied strain of a microorganism, labeled with marker genes is an effective research tool.

For the first time in our country, the above department created a genetic collection of Verticillium numbering more than 2000 strains. It permits investigation of intraspecific structure of the pathogen of wilt, which is very important to "forerunning" breeding and development of effective measures for the control of wilt.

It is known that soil is, graphically speaking, a complex living organism, and microorganisms play the most active role in its life. They process roots, stalks and leaves of plants, which remain on the field after harvesting, returning to the soil everything that had been taken from it, to restore its fertility.

The parameters of biological activity of soil were established at the Institute of Soil Science, Tajik Ministry of Agriculture, on the basis of microbiological research, and they are used in working out methods for improving fertility of this republic's long-irrigated land.

Microbiology is called upon to play an enormous role in environmental protection. As we know, we have no place to dump waste, except for the environment in which we live.

Microbiologists are working persistently on this problem, and some progress has already been made. Bacteria have been proposed that destroy toxic substances.

At the present time, about 70% of all microbiological processes are performed with the use of wild microorganisms isolated from nature. Development of cultivated races of microorganisms with increased activity or other useful properties is one of the main tasks for modern microbiology.

At the present time, this is also discussed in the USSR Food Program for the period up to 1990, and much hope is placed in development of gene engineering for breeding and developing new forms of microorganisms and plants.

The Department of General Genetics of the Cotton Plant, Tajik Academy of Sciences, together with the Institute of Genetics and Cytology, Belorussian Academy of Sciences, are conducting joint experiments dealing with transfer of foreign genetic information from one plant organism to another.

To date, the biological method of control, which is one of the basic elements of an integrated system for the protection of plants, has not gained broad popularity. Bacterial products--entobacterin and dendrobacillin--are being slowly adopted in this republic for the control of vegetable crop pests. In 1982, 100,000 ha will be submitted to biological methods of control of agricultural pests.

The cost of biologicals is still high and their efficacy at high temperature is low.

The extreme importance of further development of microbiology calls for the solution of important problems. Fruitful development of research on the borderline between natural and engineering sciences depends considerably on the joint efforts of different groups of specialists. Only proper coordination and concentration of their work would assure the ultimate success, and in this area there are still several problems to solve.

It is impossible to cultivate microorganisms for technical purposes without special equipment, which is expensive. Here, a business-like approach is needed to make joint use thereof. There are no specialized scientific departments of applied microbiology in our republic.

Nor can we overlook the question of personnel. At present, we have virtually no specialists in industrial ["technical"] microbiology. It is difficult to attract those working in other fields, and it does not always yield the desired results. Apparently, it would be expedient to establish a special interagency council on the republic level. Its main task, in addition to coordination work, should be to work out systems of measures aimed at broadening the use of microbiological advances in the national economy.

Of course, implementation of these tasks is possible only with the help and support of the Tajik Gosplan, the Ministry of Agriculture of this republic, as well as of a number of ministries that produce relevant products and compounds.

Work on the use of microbiology in the national economy requires combined efforts and a combined approach.

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ENVIRONMENT

UDC: 614.774:656.71]-074

USE OF GEOCHEMICAL INVESTIGATIVE METHODS FOR PRELIMINARY HYGIENIC ASSESSMENT OF EFFECT OF AIRPORTS ON ENVIRONMENT

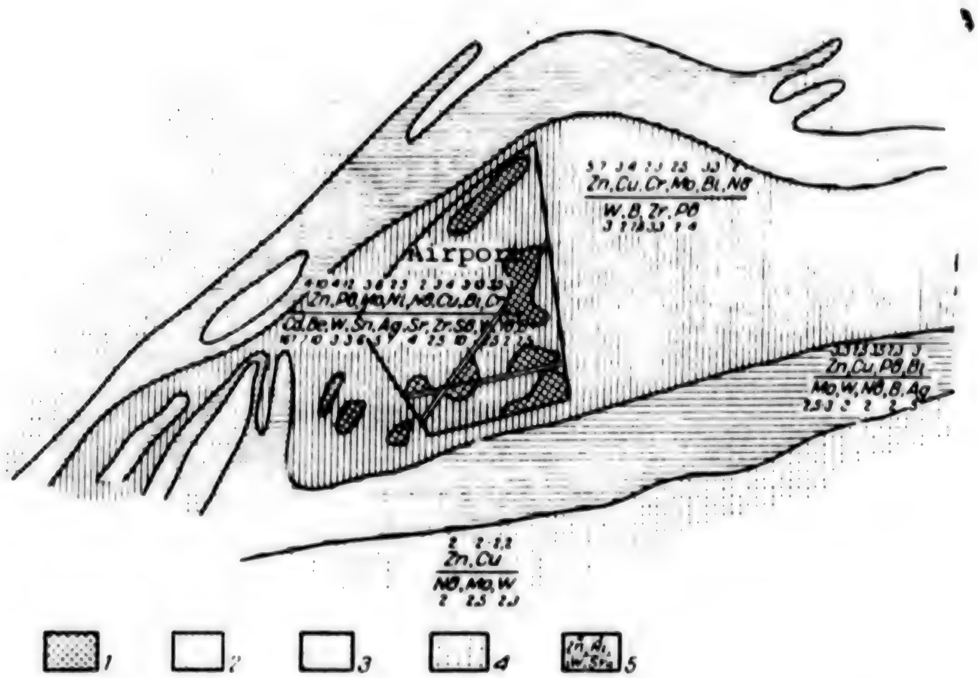
Moscow GIGIYENA I SANITARIYA in Russian No 7, Jul 82 (manuscript received 22 Dec 81) pp 63-65

[Article by V. M. Kotlyar, L. N. Pavlova and R. S. Smirnova, Central Sanitary and Epidemiological Station of the Civil Aviation, Ministry of Health, Moscow; Moscow Experimental and Methodological Geochemical Expedition of the Institute of Mineralogy, Geochemistry and Rare-Earth Elements, USSR Ministry of Geology, Moscow]

[Text] An airport is a complex functional system, which includes operation of air transport and technical services to back it up. The operation of an airport is a source of diverse effects on the environment. We refer to discharge into atmospheric air from aircraft engines, ground-based transport and stationary sources, polluted sewage, solid and liquid waste, aircraft noise, electromagnetic fields, etc.

Our objective here was to demonstrate the chemical elements specific to airports that pollute the environment and measure the range of influence of airports as a source of pollution. We conducted this work with the use of geochemical methods. The reason for their use was the conception that flows of substances into the environment from exhaust sources become included in the natural cycles of migration and generate ranges of migration of chemical elements in various elements of the landscape--soil, water and plants. The extent of the range is determined by the region containing high concentrations of chemicals (geochemical anomaly) in tested components in relation to background analogues, which were selected beyond the zone of the technogenic factors. With modern investigative methods it is virtually impossible to obtain such findings by means of direct studies of atmospheric air, which is a highly dynamic environment.

We selected a large airport for our study, with heavy air traffic, which has been operating aircraft with turbojet and turboprop engines for 20-25 years. Topographically, the region is an inclined plain with absolute altitudes of up to 200 m, made up of surface dry clay ["sukhoglinka"] lined with morainic deposits. There are agriculturally used regions adjacent to the airport, with partially retained coniferous and leaf-bearing forests on soddy podzolic soil.



Distribution of levels of airport effects on condition of the environment

1) maximal
2) strong
3) moderate
4) mild
5) associations of accumulating chemical elements

Soil testing has been done on the airport territory over a series of elevations [profiles], with distances between them of 250-500 m and testing intervals of 50-100 m. Beyond the airport grounds, one of the elevations, 12 km in length, continues in the direction of the runway. There are three elevations perpendicular to it, with a distance of 4 km between them; tests were performed at intervals of 200-250 m.

On the basis of analytical data, we gained an idea about the distribution of chemical elements on the airport grounds and around it. It was determined that the soil is polluted by a number of elements. The integral pattern of pollution was expressed by an overall pollution index (OPI), which is the anomalous load expressed by the sum of higher coefficients of concentration of chemicals in soil, as compared to background levels.

In accordance with the values for the OPI, we made a distinction between the following areas: maximum (OPI over 32), strong (OPI = 16-32), moderate (OPI = 8-16) and mild (OPI = 4-8) pollution. Their spatial positions were directly related to distance from the airport (see Figure).

At the sites of maximal pollution on airport grounds there is build-up of 19 chemical elements. The sites are referable to passenger ramps, taxiing strips, take-off points, runway, warehouses for chemicals and fuel. Beyond the territory of the airport, the sites of maximum pollution are under the flight path, at a distance of 0.6-1.2 km from the runway. There the association of elements is similar to the one found on airport grounds, with the exception of the fact that beryllium is found there, whose level exceeds the background by several times.

There is a zone of strong pollution around the sites of maximum pollution, which extends in the direction of aircraft take-off and landing for 12 km. This zone has not been outlined on the east side, which indicates that it continues in that direction. The cross-section of the zone of strong pollution is about 4 km. The spectrum of elements accumulating here numbers 10 elements (zinc, lead, niobium, tungsten, zirconium, chromium, copper, bismuth, boron and molybdenum). Beyond this zone is the zone of moderate pollution, which is characterized by accumulation of nine elements (zinc, copper, lead, bismuth, silver, molybdenum, tungsten, niobium and boron). Fewest elements accumulate in the zone of mild pollution.

A study conducted in the winter of the snow cover on airport grounds and in the zone it affects revealed that melted snow contained nitrous and sulfur oxides in excess of background levels, which is indicative of the fact that the airport is a source of such pollutants. At the same time, there is a very definite spatial relationship that was demonstrated between the zone of high levels of nitrogen and sulfur in snow and the zone of strong pollution of soil by chemical elements, which confirms once more the atmospheric route of their migration into soil.

A study was also made of the condition of superficial streams [channels] that drain the territory of the airport and the closest rivers and streams. There are no large bodies of water in the area affected by the airport. These studies were pursued in the summer. They revealed that the composition of water is primarily hydrocarbonate and calcium. Water mineralization is in the range of 350-700 mg/ℓ; its reaction is neutral and, in some cases, mildly alkaline. Total potassium and sodium ions in water are close to the maximum permissible concentrations. There is a high phosphate and nitrogen compound content.

The high levels of potassium, sodium and phosphorus compounds are apparently related mainly to agricultural activity, since these elements are contained in fertilizers and herbicides. However, when water is polluted by an agricultural source the nitrogen level is considerably lower than in the zone affected by the airport we studied. This is indicative of the role of the aircraft source in water pollution. In some parts of the streams and brooks, there are high levels of trace elements in water: copper, cadmium, zinc, fluorine, strontium, nickel, molybdenum and manganese. In bodies of water into which superficial drainage flows directly from the grounds of the engineering services and warehouses for fuel and lubricants, there is accumulation of zinc, nickel and, particularly, manganese. In the water of brooks into which surface drainage flows from an aircraft repair plant situated next to the airport, high concentrations of strontium, cadmium, molybdenum, chromium were detected, and there are elevated levels of manganese and nickel. High indicators of pollution were found from a study of bottom deposits. While maximum pollution in soil was characterized by an OPI of no more than 50, there it increases to 120. Associations are characterized by a broad spectrum of accumulating elements. Silver and vanadium build up in all bottom deposits. Among the other anomalous elements encountered in soil, we found chromium, molybdenum, cobalt, zinc, lead, nickel and tin.

A comparison of geochemical informativeness of water and bottom deposits revealed that the latter stably fix the sources of water pollution, permit forming a spatial idea about the zones affected by pollution sources, as well as more accurate detection of elements that pollute waters and adjacent territories.

A study of vegetation revealed that, in the zone of maximum pollution, there were high levels of several chemical elements in grassy plants, including strontium, barium, manganese, nickel, copper, zinc, tin and molybdenum. The coefficients of concentration thereof constitute 8, 4, 3, 3, 4, 5, 2 and 3, respectively. In grassy plants in the zone of strong soil pollution, there are abnormal concentrations of yttrium, zirconium, titanium, vanadium, gallium, lead and hafnium.

Considering the biological effects of metals and a number of other elements, it can be expected that our findings will guide the researcher to an in-depth study of airports as the source of migration of these elements into the environment, including biological objects, with the inclusion of man. Further dynamic observations of this airport and investigation of analogous enterprises are necessary in order to determine the degree of stability of the nature and boundaries of polluted areas.

Thus, the results of this study indicate that the airport pollutes the environment with chemical elements. For the territory of the airport we have demonstrated high concentrations of 19 chemical elements in soil, the presence of which is related to operation of the airport as an industrial zone. We also demonstrated zonality of intensity of soil pollution change in associations of elements that build up, and the localization of the zones of the most intensive pollution is related to the sites of prolonged or forced operation of aircraft engines. We established a link between the zone of strong pollution of soil by chemical elements and zones where snow contains sulfur and nitrogen compounds, which is indicative of the atmospheric route of migration of pollutants into soil. We were impressed by the fact that the chemical elements-pollutants are absorbed from soil by plants, which could lead under certain conditions to migration thereof in large amounts to animals and man. Soil and bottom deposits of bodies of water are the most demonstrative for the study of the patterns of airport pollution of the environment.

The data we obtained could be used to work out measures for lowering the influence of airports on the environment.

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SOME PATTERNS OF DISTRIBUTION OF POLLUTANTS IN SEAPORT WATERS

Moscow GIGIYENA I SANITARIYA in Russian No 7, Jul 82 (manuscript received 4 Jan 82) pp 66-69

[Article by V. A. Kolodenko, Yu. I. Gutsel' and N. N. Nadvornyy, Basin Water Transport Sanitary and Epidemiological Station, Odessa Medical Institute imeni N. I. Pirogov]

[Text] Examination of the qualitative composition and quantitative distribution of pollutants in waters, study and demonstration of the main patterns of self-purification processes in sea waters constitute an important aspect of the problem of sanitary protection of the seas (Yu. V. Novikov et al.). The work done in our country with regard to the study of these patterns and regulation of pollution of the marine environment (A. S. Gorodetskiy and B. M. Raskin; L. V. Grigor'yeva; G. I. Sidorenko et al.; V. G. Subbotin et al., and others) is of great practical importance. The results obtained served as the basis for existing standards and methodological recommendations.

It must be noted that most studies dealt with these patterns in open coastal regions. As for studies of distribution of pollutants in sections of the sea circumscribed by hydraulic installations, including seaport waters, there are very few of them (V. A. Yakovenko; G. A. Tsaturova) and they do not provide the complete picture of changes in the sanitary situation in them under different meteorological and hydrological conditions. This, in turn, affects the quality of organizing inspection of sanitary condition of seaport waters and adjacent water-use regions. It is difficult to determine the optimum sections for collection of samples, which leads to unwarranted increase in number of laboratory tests.

Our objective here was to investigate the main patterns of distribution of pollutants in seaport waters under different meteorological conditions and to determine the optimum sites for laboratory monitoring of the changing sanitary state of sea water.

These studies were conducted in the waters of one of the ports in the northwestern part of the Black Sea, in the absence of organized dumping of sewage and industrial waste. The hydraulic installations (retaining walls, breakwaters, etc.) of this port are typical of ports on the Black Sea Coast.

We selected 4 sites for observation: 1) near the mooring line, 2) center of the harbor (250 m from the moorages), 3) before the breakwater (500 m from moorages), 4) beyond the breakwater (750 m from moorages). The first three sites were characterized by a sanitary state of waters as a whole.

Change in sanitary indicators during tide activity in port waters

Parameter		Change in sanitary parameters														
		at mooring line			middle of harbor			before breakwater			beyond breakwater			for waters as a whole		
		mean data	rising water	falling water	mean data	rising water	falling water	mean data	rising water	falling water	mean data	rising water	falling water	mean data	rising water	falling water
Oxidizability, mg/ℓ	$\bar{X}$	3,78	2,85	4,50	3,70	3,00	4,52	3,22	2,97	3,59	3,37	3,25	3,70	3,59	2,97	4,31
	m	0,30	0,30	0,34	0,14	0,08	0,26	0,07	0,14	0,12	0,39	0,53	0,12	0,10	0,09	0,17
BOD$_5$, mg/ℓ	$\bar{X}$	5,90	3,34	8,40	5,15	5,08	5,49	4,25	4,00	4,71	4,88	4,28	6,02	5,25	4,25	6,07
	m	0,80	1,00	0,40	0,25	0,30	0,43	0,48	0,62	0,43	0,40	0,26	0,63	0,19	0,25	0,28
Salinity ‰	$\bar{X}$	11,41	15,50	8,35	13,20	14,57	11,58	13,27	12,90	13,76	12,54	14,55	9,33	12,90	13,64	12,06
	m	1,12	0,58	0,70	0,33	0,20	0,54	0,53	0,77	0,75	1,11	1,25	0,64	0,34	0,38	0,52
Surfactants μg/ℓ	$\bar{X}$	71,00	75,00	60,00	185,00	150,00	230,00	119 00	76,00	185,00	130,00	153,00	100,00	144,00	118,00	175,00
	m	8,00	14,00	7,00	12,00	30,00	30,00	19,00	18,50	43,60	19,00	27,00	8,00	6,00	9,00	10,00
Petroleum prod. mg/ℓ	$\bar{X}$	0,89	1,28	0,65	2,27	3,29	0,90	1,19	0,92	1,47	3,04	4,35	1,21	1,77	2,52	0,96
	m	0,14	0,39	0,10	0,23	0,50	0,14	0,22	0 31	0,39	0,37	1,64	0,10	0,11	0,15	0,15
Bacterial number/a	$\bar{X}$	225,00	144,00	300,00	11,00	2,00	36,00	29,00	3,30	54,60	29,00	0,14	65,00	73,40	37,50	123,50
	m	40,00	75,00	100,00	2,00	0,30	11,00	16,00	1,40	27,00	10,40	0,08	18,00	15,90	4,70	37.00
Coli index/a	$\bar{X}$	88 500	100000	90 000	1250	500	16 000	500	105	2380	170	96	238	41 800	44 600	38.700
	m	20 500	25 000	2 100	200	250	2 840	250	51	305	25	3	1	800	1 280	14,000

To study the effect of tide activity [water surges] on the sanitary state of port waters and distribution of pollutants in water, samples were taken in the summer (July-August) from the water line and at a depth of 10 m. Additionally, samples were collected in the winter (December-January) at 5-10 cm in order to determine the extent of effects of seasonal fluctuations on sanitary indicators. A total of 210 samples of sea water were collected and tested in 1978-1979.

The distribution of pollutants was assessed according to change in sanitary-chemical (oxidizability, BOD$_5$ [biochemical oxygen demand], salinity, surfactants--surface-active petroleum products) and sanitary-biological (coli index, total bacterial number) parameters. The results were submitted to statistical processing by the conventional methods of sanitary statistics. A constant coefficient (a) was used to facilitate processing of bacteriological data.

Observations of vertical distribution of pollutants in seaport waters showed that oxidizability of water and BOD$_5$ were lower at a depth of 10 m than in samples taken on the surface. The difference between mean values for the port waters as a whole constituted 0.68 and 1.49 mg/ℓ ($P = 0.01$), respectively, in absolute numbers. Water salinity was lower on the surface than in depth. The difference between mean values was reliable and, in absolute numbers, constituted 1.58%.

Total number of microorganisms was higher in samples taken from the surface than in deep water. The difference in absolute numbers constituted an average of 50.28 for the waters as a whole, 199.3 ($P = 0.01$), 2.3 ($P = 0.05$), 3.5 ($P = 0.5$) and 28.4 ($P = 0.05$) for the different sites. There was a distinction to the distribution of colibacilli near the mooring line. The coli index was higher in samples taken at a depth of 10 m than on the surface ($P = 0.01$). We can attribute the increase in quantity of colibacilli near the mooring line at a depth of 10 m to accumulation of pollutants near the moorage during water rises and intensive mixing thereof, as well as run-off from the moorage.

This was confirmed by the analogous distribution of BOD_5 levels. At the mooring line they were higher at a depth of 10 m than on the surface. The difference in absolute BOD_5 at the moorage at a depth of 10 m and analogous parameters constituted 4.6 mg/ℓ in the middle of the harbor, 4.4 mg/ℓ before the breakwater and 4.16 mg/ℓ beyond the breakwater ($P = 0.01$). As for petroleum products, they were evenly distributed vertically near the mooring line. In other parts of the harbor, the amount thereof was greater in the superficial layer than at the 10-m mark ($P = 0.05$). We failed to demonstrate differences in surfactant concentrations in different depths of water.

We assessed the effect of meteorological factors on sanitary state of the waters by comparing sanitary-chemical and sanitary-bacteriological parameters during water rising and falling activity.

As can be seen from the submitted data (see Table), oxidizability of water diminished reliably during rises and increased during falls. Differences between mean values in port waters constituted 1.34 mg/ℓ ($P = 0.01$). The degree of difference diminished as the distance from shore increased. They were unreliable beyond the breakwater. The confidence limits of the sample as a whole constituted 2.19-5.18 mg/ℓ. The parameters in the center of the harbor were closest to this sample (2.85-5.04).

BOD_5 underwent analogous changes. The difference between their mean values were the most significant near the mooring line (5.06 mg/ℓ). BOD_5 levels close to the parameters for the entire seaport waters (3.75-6.63 mg/ℓ) were demonstrated in the center of the harbor with confidence limits of 4.48-6.35 mg/ℓ. During drops in water level there was reliable elevation of BOD_5 levels beyond the seaport waters.

It was established that tidal activity also has an appreciable effect on degree of salinity of water in the port. The difference between mean salinity levels in absolute numbers constituted $+4.09^0/_{00}$ ($P = 0.01$) during rises and $3.06^0/_{00}$ ($P = 0.05$) during falls. There was also a reliable decrease in salinity during falls beyond the breakwater ($3.21^0/_{00}$). Salinity levels were closest to these in the middle of the harbor (10.50-$14.97^0/_{00}$).

Tidal activity had no appreciable effect on distribution of surfactants in seaport waters. Changes occurred in concentration thereof mainly in the area of hydraulic installations protecting harbor waters. The most typical concentrations of surfactants for the seaport waters as a whole were found in the middle of the harbor, with confidence limits of 90-290 μg/ℓ.

There were considerable changes in concentration of petroleum products under the effect of these factors [tidal activity]. Maximum amounts of petroleum products were demonstrable during rises in the center of the harbor and beyond the breakwater, and during falls before and beyond the breakwater.

Water surges also have an appreciable effect on distribution of allachthonic microflora in seaport waters. The differences between mean coli index values for the waters as a whole were reliable with this activity (P = 0.05). In both instances, maximum coli index levels were demonstrated at the mooring line. The coli index in the center of the harbor, before and beyond the breakwater during drops exceed the analogous parameter during rises by 32, 22 and 2 times, and diminished as the distance from the shore increased. These changes are attributable to dilution processes due to migration of clean water from the open sea during rises, whereas during falls there was migration of pollutants from the moorage both into the seaport waters and beyond them.

Analogous changes were demonstrated in distribution of saprophytic microflora. Maximum quantities thereof during tidal activity were found near the mooring line. They diminished as the distance from shore increased. There was slower decline in total quantity of microorganisms during drops than falls.

In our studies, there was an inverse correlation between total number of microorganisms, concentrations of surfactants ($r = 0.84$) and oil products ($r = 0.69$).

Studies of the effect of seasonal fluctuations on sanitary parameters revealed that water oxidizability was higher in the summer months than in the winter (P = 0.01). In absolute numbers, this difference constituted 0.51 mg/ℓ. There were analogous changes in BOD_5. The difference between mean values for the seaport waters as a whole constituted 2.80 mg/ℓ (P = 0.05). Such changes could be due to intensive development of phytoplankton in the summer months and increased access of readily oxidized organic matter. The salinity indicators for the seaport waters are indicative of the validity of this conclusion. They were higher at the mooring line in the winter than in the summer, and in absolute numbers this difference constituted 1.24% (P = 0.05).

The concentrations of surfactants were higher in seaport waters in the winter months than in the summer, which could be attributed to the intensity of biochemical processes in the summer (Ye. A. Mozhayev). The difference in mean concentrations for seaport waters as a whole constituted 136 μg/ℓ (P = 0.05). Maximum concentrations of surfactants (300 μg/ℓ) in the wintertime were found at the mooring line and minimum (70 μg/ℓ) beyond the breakwater. The confidence limits of mean values for the seaport waters as a whole constituted 174-316 μg/ℓ.

Seasonal fluctuations also have a substantial influence on allachthonic microflora. Absolute values of the coli index at the different sites were higher in the summer than in the winter by 1427, 43, 0 and 1.3 times. The difference between mean values for the waters as a whole constituted 41,520 (P = 0.01). The indicators of total number of microorganisms were higher at the different sites in the summer months than the analogous values for the winter months by 98, 4, 45 and 46 times. The difference as a whole for the water constituted 71 (P = 0.01).

In order to determine the extent of effect of the hydraulic installations on self-purification processes, we calculated the frequency of horizontal dilution (using the formula for mixing two water masses; L. K. Leyesment et al.) for the different sanitary parameters of the seaport waters. As base values we took the pollutant levels at the mooring line during falls of water. We compared the results to parameters of dilution frequency obtained for open coastal regions (Ye. F. Shul'gina et al.).

These studies revealed that the rate of dilution of liquid sewage was much lower in seaport waters than in coastal regions. Presence of the protective hydraulic installations is the chief cause of slower dilution of sewage in seaport waters.

Conclusions

1. Hydraulic installations lead to change in horizontal stratification and create conditions for accumulation of pollutants in the upper layers of waters the sanitary state of which depends largely on hydrometeorological factors and seasonal fluctuations.

2. Because of intensive mixing processes at the mooring line during water rises, the distribution in depth of organic matter, surfactants, petroleum products is more uniform than in other parts of the port. Colibacillus content is somewhat higher in deep layers of water than on the surface.

3. When organizing permanent laboratory monitoring of sanitary condition of seaport waters, it is desirable to collect samples for sanitary-bacteriological tests near the mooring lines and for sanitary-chemical tests in the middle of the water area. There should be about the same number of samples collected during rising and falling of water. It is necessary to define additional observation stations on the boundary between the water-use zone and area of possible drift of pollutants between water-use zone and the seaport when determining the extent of influence of the port on sanitary state of adjacent water-use regions. Samples are taken only during periods of falling water.

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EPIDEMIOLOGY

PREPARATIONS FOR PREDICTED INFLUENZAL OUTBREAK IN RIGA

Riga SOVETSKAYA LATVIYA in Russian 24 Oct 82 p 4

[Article by A. Blyuger, academician of the Latvian SSR Academy of Sciences and Head of the Department of Infectious Diseases, Riga Medical Institute: "We Shall Block the Progress of Influenza"]

[Text] In recent years Soviet medicine has achieved substantial successes in the control of influenza. Effective methods were developed for its diagnosis, treatment and prophylaxis; there was worked out a complex of organizational measures which, considering the vast scales of propagation of influenza, play an important role in its control both before and during epidemics. The specific prophylaxis of this disease with anti-influenzal vaccines and chemical preparations became possible owing to the achievements of medical science. A system of prognosis was developed, making it possible to identify specific influenzal viral agents that circulate among the population, to predict increases in morbidity and to foresee the threat of an epidemic. This system, acting not only in our nation but throughout the world, provides, in particular, the opportunity to prepare in advance for an outbreak of morbidity and to activate in time a whole complex of measures holding the infection as if in the ring of a blockade.

According to the data of the World Health Organization, three principal forms of influenzal virus--A_2 (Hong Kong), A_1 and B--circulated in the world's population during the first half of the current year. At the same time, epidemic outbreaks of local importance caused by the A_2 and A_1 viruses were recorded in a number of nations in Europe and Asia. Similar outbreaks associated with the A_1 virus were observed within the Soviet Union back in November-December 1981. This same virus also predominated in the epidemic process within the USSR during the first half of 1982. Therefore, our level of collective immunity to A_1 influenza has increased considerably, i.e., there increased the fraction of the population that is nonreceptive due to the presence in the blood of specific protective antiviral antibodies (produced as a result of previous contact with the virus). According to data on May 1982, the collective immunity to A_1 influenza in various cities of our nation fluctuated at an adequately high level. The probability of an epidemic rise in morbidity by this form of infection is small.

An increase in morbidity caused by the A_2 (Hong Kong) influenzal virus is expected during the present autumn and the forthcoming winter. What is the basis for this prognosis? There have been noted, first, a comparatively low level of collective immunity in the population (especially among children born after the largest of the past epidemics of this influenzal virus in 1968) and, second, an increased activity in the circulation of the A_2 virus in certain regions of the world. Children will apparently be primarily affected if an influenzal epidemic develops. A certain "revival" of the type B influenza has not been excluded, but this form of infection dees not usually give a great rise in morbidity and does not involve large contingents of the population.

The intensified circulation of types A_2 (Hong Kong) and B viruses is confirmed by the fact that an increase in the level of antibodies to specifically these viruses has already been noted in a portion of the population of our nation. It is known that such a phenomenon is usually observed three to four months prior to an epidemic rise in morbidity.

The organs of public health have a comprehensive plan for anit-influenzal measures, which will be activated in stages. Considering the developing situation, the Latvian SSR Ministry of Health has activated the first stage of the plan. It is based on the massive vaccination of the population.

Why is vaccinal prophylaxis necessary? It is known that during epidemics morbidity rises especially sharply in large cities with a high population density, close contacts between people, a developed transport system, etc. This is why the vaccination of the inhabitants of Riga, which is presently being carried out, is of decisive significance for reducing the spread of the infection in the republic.

The greatest antiepidemic effect is provided by a single vaccination of large contingents of the population--at large enterprises, VUZs, etc. Several types of influenzal vaccines exist. Their effectiveness and safety are approximately the same. Adults (18-55 years) are vaccinated with a liquid inactivated ("killed") influenzal vaccine, which is injected intracutaneously using neddleless injectors.

The vaccination is a one-time vaccination and does not cause unpleasant sensations. The procedure lasts several seconds, and with good organization a medical workers brigade can service several hundred people in one hour.

For the prophylaxis of influenza in adults who for whatever reason have not undergone vaccination, a vaccine can be used that is administered into the nasal passages twice with a 20-30 day interval. Children of from 3 to 14 years of age receive an oral vaccine (three times with a 10-day interval) at kindergartens or schools.

The immunization of the citizens of Riga has been conducted since 1 October of this year. Experience shows that a high antiepidemic effect is achieved if a minimum of two thirds of the population is subjected to vaccination. This is the extent of immunization planned by the Ministry of Health for the inhabitants of the Latvian capital. The feasibility of these plans in large measure depends upon an intelligent attitude of the population towards vaccination and the assistance to the health organs on the part of the leaders of enterprises, institutions and scientific establishments.

The next stage in the complex of antiepidemic measures is emergency influenzal prophylaxis directly during the epidemic.

The best means of such prophylaxis during type A influenza is presently remantadin, a preparation developed, tested and produced in our republic and widely used throughout the nation. It is taken (only by adults) for prophylactic purposes at a rate of one tablet per day during the height of the epidemic for 20-30 days (it is recommended that coffee and alcohol consumption be strictly limited when taking remantadin). The use of remantadin, as we have established, lowers the risk of influenzal infection two- to threefold.

Of definite effectiveness is oxole ointment, administered with a cotton wad deep into the nasal passages. Emergency influenzal prophylaxis in organized collectives (enterprises, institutions, etc.) is carried out according to the instructions of the republic sanitary epidemiological service, which monitors the situation with respect to influenza. The population will be informed of the need for such prophylaxis in good time through the mass media. This prophylaxis is especially important for people that are subject to a high risk of infection by the nature of their work (workers in transport and trade, medical workers, etc.) and also for older people suffering chronic illnesses. and people in contact with a patient--family members, neighbors, etc.

Although we possess effective means for the vaccinochemical prophylaxis of influenza, all well-known sanitary measures retain their importance. The danger of influenzal propagation in large degree is determined by the behavior of the patient himself. An intelligent attitude of patients to the health of the surrounding people can "dampen" an epidemic outbreak. We recall once more the necessity for the maximum restriction of social contact (including those with relatives) upon appearance of the first symptoms of the illness. An influenzal patient should not visit the polyclinic during the acute period; the phsyician must make a house call.

Other measures for influenzal control will be carried out during an epidemic rise in morbidity: restriction of contacts between people, the wearing of masks by workers in the service sphere, quarantine in therapeutic institutions, mobilization of transport for medical purposes, involvement in the control of the infection of students in advanced courses at the Riga Medical Institute, allocation of supplementary sites in hospitals for the treatment of patients with severe forms of the infection, etc.

Accumulated experience permits the hope that the medical workers of the republic with the active participation and cooperation of party and Soviet organs and the leaders of enterprises and institutions will be able to erect a barrier against the impending influenzal epidemic.

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GENETICS

ORGANIZATION OF INSTITUTE OF GENETICS, USSR ACADEMY OF SCIENCES

Moscow PRIRODA in Russian No 6, Jun 82 pp 85-86

[Excerpt from article about Yu. A. Filipchenko and N. I. Vavilov--geneticists and evolutionists]

[Text] The fates of Filipchenko and Vavilov were joined the most closely in the matter of organizing our country's first academic genetic institution. We are referring to the founding of the Institute of Genetics, USSR Academy of Sciences, in Leningrad, an institution that was converted after several reorganizations into the current Institute of General Genetics. The history of its creation is instructive; it graphically shows what a creative and benevolent atmosphere prevailed in Soviet genetics in the late 1920's and early 1930's.

Starting in 1925, Filipchenko redirected his work and that of his immediate colleagues away from problems of human genetics to investigation of genetics of animals and plants, mainly those referable to agriculture. Accordingly, the Eugenics Office [or bureau], which Filipchenko had previously organized in the system of the Academy of Sciences, began to be called the Office of Genetics and Eugenics and, a few years later, the Office of Genetics. The "Izvestiya" [News], which it published anually, contained only articles dealing with work on experimental objects starting with No 4 (1926). This is how the first genetic branch ["cell"] appeared in the Academy of Sciences and the first genetic publication appeared in our country.

The staff of this office was extremely small, and its permanent members consisted only of Filipchenko's first disciples, T. K. Lepin and Ya. Ya. Lus. However, starting in 1926, under the aegis of the Office, extensive expeditionary studies were pursued and there was rapid growth in volume of work. Concurrently, by the late 1920's, the department of genetics of Leningrad University had trained a large detachment of young talented and highly qualified geneticists, and conditions were provided for reorganizing the Office with expansion of its staff and tasks. Such reorganization had already been planned before Filipchenko's death, and in October 1930 the Office, which had been part of the Commission for the Study of Natural Productive Forces, became an independent Academy institution, the Laboratory of Genetics, USSR Academy of Sciences. But officially, this event occurred several months after the death of Filipchenko and, of course, the question arose as to who would head the laboratory. Filipchenko's closest colleagues turned to

Vavilov, whom they knew well and for a long time, with the request that he head the new institution. In 1929, Vavilov was elected to active membership in the USSR Academy of Sciences. At that time, he also became president of the All-Union Academy of Agricultural Sciences imeni V. I. Lenin, while continuing as director of the All-Union Institute of Plant Growing.

What prompted Vavilov to also take on the management of a new institution? Probably there were several reasons: both the desire to support a group, that had been left without leadership when it had just become independent and, mainly, the desire to carry out some of his ideas in the area of genetics, not all of which would have been developed at the All-Union Institute of Plant Growing which was applied in orientation.

Be that as it may, Vavilov also became the head of the Laboratory. The first thing he did was to gather in the Laboratory all of the young disciples of Filipchenko: M. L. Bel'govskiy, B. I. Vasil'yev, B. P. Voytyatskiy, Yu. L. Goroshchenko, Yu. Ya. Kerkis, D. M. Kershner, N. N. Kolesnik, N. N. Medvedev, A. A. Prokof'yeva, Ye. P. Radzhabli, B. F. Rumyantsev and N. Ya. Fedorova. There is no need to say that none of the old staff of the Office left under the new head.

Vavilov's ability to impart a global scope to any job that he undertook was fully manifested in his administration of the Laboratory. In 1933, the Laboratory already developed into an Academy Institute of Genetics, to which Vavilov tried to lend an international orientation and to transform it into a worldwide genetics center (an idea that was fully realized only after several decades, and then not in the area of biology, but physics, with the foundation of the Unified Institute of Nuclear Research in Dubno). The greatest Soviet geneticists, A. A. Sapegin and G. A. Levitskiy, as well as the talented Bulgarian cytogeneticist, D. Kostov, and the outstanding American geneticists, C. Bridges and H. Meller (who worked at the institute for several years and subsequently became a Nobel Prize recipient) were invited to work at the institute. There were other foreign scientists also.

The new institute was located on Makarova Quay, in a building presently occupied by the Institute of Physiology, USSR Academy of Sciences, where Filipchenko was given his first laboratory rooms as far back as February 1929.

There was a drastic expansion of the range of scientific directions, in which the institute worked. In 1934 there were 5 of them: "1) development of teaching on mutations and allied problems of the gene, 2) interspecific hybridization, 3) material bases of heredity, 4) inheritance of quantitative characters, 5) origin of domestic animals and cultivars."*

While the first three directions were established by Vavilov himself, the last two continued the work begun by Filipchenko. His disciples, T. K. Lepin and Ya. Ya. Lus remained as the leading workers in these directions.

In 1934, a decree was adopted to transfer the USSR Academy of Sciences to Moscow, and that is where the Institute of Genetics located, along with other institutions, in the fall of 1934. This move marked the turn to the next stage in activities of this institute. At the same time, a new stage also began in the history of Leningradian genetics, which had been immediately deprived of both its principal research center and many talented young geneticists.

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*Vavilov, N. I., VESTNIK AN SSSR, No 5, 1934, p 1.

At the funeral of Filipchenko, at the Smolensk Cemetery in Leningrad, Vavilov said: "Yuriy Aleksandrovich was not only a brilliant scientist, but a human being, and nothing human was foreign to him. But the weak points of his nature will be forgotten even before the fresh mound over his grave is covered by green shoots. His grateful descendants will, however, remember him as that rare combination of courage, talent and personal example of selfless service to science and homeland, which left a deep mark in the development of Soviet biology."*

In the forework to Filipchenko's book, published 5 years after his death, Vavilov wrote: "The author of this book, who is unfortunately no longer with us, is an outstanding Soviet geneticist. His genetic research is widely known in circles of geneticists and breeders far beyond the frontiers of our country."

"Yu. A. Filipchenko has rendered absolutely exceptional services as a brillinat and talented educator and author of several textbooks of genetics. He was the first to broadly popularize genetics in our country. An entire generation of breeders and geneticists studied and is studying under his guidance...."

"... A strong theory is needed to deploy enormous breeding work in practice. In this respect, this book by Yu. A. Filipchenko is exceptionally timely. It will serve as the beginning of development of breeding theory, which we need, to develop economically valuable breeds of animals and plants."**

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LASER EFFECTS

UDC: 575.224.46+577.3

COMPARATIVE MUTAGENIC EFFECTIVENESS OF GAMMA AND LASER RADIATION

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 26, No 8, Aug 82 (manuscript received 28 Dec 81) pp 753-756

[Article by V. G. Volodin, V. A. Mostovnikov, B. I. Avramenko, Z. I. Lisovskaya and I. V. Khokhlov, Institute of Genetics and Cytology, Belorussian Academy of Sciences (presented by L. V. Khotyleva, academician of the Belorussian Academy of Sciences)]

[Text] In recent years, it was shown that laser radiation can be used for breeding as a new mutagenic factor [1-5]. However, the question of relative efficacy of this new mutagen is still open. Contradictory data are submitted in the literature concerning the effectiveness and desirability of using laser light to induce mutations in agricultural plants [6-8].

Our objective here was to determine the genetic effectiveness of laser radiation, as compared to gamma radiation. We used cultivars and mutants of spring wheat and barley as the objects of our study.

The experimental set-up involved the following: exposure of air-dried seeds to gamma rays (dose rate 0.017 A/kg) in the most effective doses (1.3-2.6 C/kg for wheat and 2.6-5.2 C/kg for barley) and laser radiation at different wavelengths. We used a monopulse ruby laser ($\lambda = 694$ nm, 10^8 W/pulse), "Samotsvet" pulsed dye laser ($\lambda = 450$-465 nm, 10^5 W/pulse), continuous-wave argon laser ($\lambda = 476$ nm, 1 W) and helium-cadmium laser ($\lambda = 442$ nm, $3\cdot10^{-2}$ W).

Irradiated seeds were immediately sown in the field. The main spikes of first-generation plants (M_1) were strictly isolated. Selection and typing of phenotypically altered plants were performed in the second generation (M_2). The following year, we analyzed inheritance of altered characters in each family. The first series of experiments was performed with the Leningradka cultivar of spring wheat. We used gamma radiation in the most mutable dosage of 2.6 C/kg for this variety [9], a helium-cadmium laser generating radiation in the blue region of the spectrum, as well as continuous argon laser (Table 1). It was determined that laser light with specific parameters has marked mutagenic activity. The incidence of altered families in M_2 ranged from 17 to 29%, depending on the parameters of laser radiation. Helium-cadmium lasers ($\lambda = 442$ nm), with radiation dosage of $7\cdot10^5$ J/m^2, was found to be the most effective. In this variant, we found 29% altered families, i.e., about the same amount as when seeds were exposed to gamma radiation.

Table 1. Hereditary variability of Leningradka wheat under the effect of gamma radiation and laser light (with $P<0.01$)

Irradiation variant	Families analyzed	Altered families in M_2, %	Inheritance in M_3, %
Control	200	0	—
Gamma radiation, 2.6 C/kg	97	27	46
Light $\lambda = 442$ nm, $7 \cdot 10^5$ J/m^2	111	29	45
$\lambda = 442$ nm, 10^6 J/m^2	94	19	90
$\lambda = 476$ nm, $4 \cdot 10^6$ J/m^2	126	17	52

Table 2. Hereditary variability of genotypically different forms of wheat under the effect of gamma and ruby laser radiation (dosage $12 \cdot 10^5$ J/m^2)

Genotype	Irradiation variant	Famil. analyzed	Altered famil. in M_2, %	Inheritance in M_3, %	Reliability of differences between experiment & control
MT-4 form	Control	147	0	—	—
	γ-rays 1.3 C/kg	284	4,2	83	$P < 0{,}05$
	2.6 C/kg	125	16	75	$P < 0{,}01$
	Light $\lambda = 694$ nm	104	26	88	$P < 0{,}01$
MT-13 form	Control	143	0	—	—
	γ-rays 1.3 C/kg	241	4,9	50	$P < 0{,}05$
	2.6 C/kg	67	2,9	67	—
	Light $\lambda = 694$ nm	110	0	—	—
Tulun-70	Control	197	0	—	—
	γ-rays 2.6 C/kg	110	3,6	75	$P < 0{,}05$
	Light $\lambda = 694$ nm	90	15	85	$P < 0{,}01$

It should be noted that plant survival was considerably lower after exposure of seeds to gamma radiation than after lasers. This could be indicative of higher incidence of gamma-induced lethal mutations and, in this respect, the superiority of laser radiation.

Examination of M_3 offspring of altered plants revealed that less than half the families in the gamma radiation variant and over half the families in the test with lasers inherit the mutant character. We singled out one variant (helium-cadmium laser, $\lambda = 442$ nm, dosage 10^6 J/m^2), in which the incidence of inheritance of mutant families constitutes 90%. On this basis, it is suggested that the above-mentioned type of laser be used for induction of mutations in the Leningradka cultivar of spring wheat zoned in BSSR.

In the second series of experiments, we evaluated the mutagenic effect of the strongest of single pulse ruby lasers we used ($\lambda = 694$ nm, energy 10^8 W, dosage $1.2 \cdot 10^5$ J/m^2), also in comparison to gamma radiation. The experimental set-up was more complex due to use of Tulun-70 cultivar and two mutants, MT-4 and MT-13, obtained from this cultivar. The use of mutants enabled us to follow more accurately the role of genotype in responses to laser radiation.

The studies revealed (Table 2) that the light from a ruby laser also induces phenotypically altered families in M_2 at a rather high frequency (15-26%). As can be seen in Table 2, the yield of altered families in M_2 of Tulun-70 cultivar constituted only 3.6% after gamma irradiation, whereas the figure rose to 15% with lasers. The second distinction, to which we should call attention, is that there was distinct demonstration in this experiment of the difference between mutants originating from the same cultivar with regard to reaction to exposure to different mutagenic factors. It was found that mutant MT-4 was more mutable than the original cultivar and mutant MT-13. It reacted rather effectively to both ionizing and laser radiation. In this mutant, the incidence of altered families in M_2 constituted 16 and 26%, respectively. We observed somewhat less mutability of mutant MT-13 than of the cultivar in the case of exposure to gamma radiation, and absence of visible morphological changes after exposure to laser light.

Table 3. Hereditary variability of barley under the effect of gamma and laser radiation

Cultivar	Irradiation variant	Famil. analyzed	Altered famil. in M_2, %	Inheritance in M_3, %	Reliab. of diff. betw. exp. & control
Nadya	Control	400	0	—	—
	γ-rays				
	1.3 C/kg	181	1,7	67	—
	2.6 "	290	0,3	100	—
	3.9 "	527	4,0	34	$P < 0,01$
	5.2 "	440	6,9	30	$P < 0,01$
	Light λ				
	442 nm, 10^6 J/m^2	203	4,4	44	$P < 0,05$
	663 nm, 10^6 J/m^2	565	5,1	74	$P < 0,01$
	450-465 nm, 40 J/cm^2	491	8,4	60	$P < 0,01$
Mami	Control	400	0	—	—
	γ-rays, 5.2 C/kg	262	6,9	33	$P < 0,05$
	Light λ = 442 nm, 10^6 J/m^2	203	0	—	—

Thus, the second series of experiments confirmed the efficacy of laser light as a mutagenic factor. It should be borne in mind that use of plants of different genotypes for irradiation, without comparative evaluation of their reaction to lasers, could lead to contradictory conclusions as to the prospects of using lasers in breeding programs.

Analogous results were obtained in experiments with barley (Table 3). Here, we should mention the fact that both gamma and laser radiation was less effective on this plant with regard to total number of morphologically altered forms than in wheat. While the maximum incidence of altered families in M_2 constituted 26-29% in laser variants used on wheat, it constituted 5.1-8.4% with barley, whereas in the variants with gamma radiation the figures were 16-27% for wheat and 4-7% for barley. The experiments with barley also revealed the specificity of genotypes with use of lasers. Thus, we failed to obtain morphologically altered forms of the Mami cultivar with exposure to helium-cadmium laser. At the same time, with the Nadya cultivar, exposure to this laser resulted in about the same yield of altered forms as after exposure to gamma radiation in a dosage of 3.9 C/kg. There was greater inheritance of the demonstrated phenotypic changes in barley exposed to lasers than to the variants of gamma radiation.

Analysis of the spectrum of induced variability in wheat and barley revealed that, along with change in the same plant characters under the effect of both factors, there were also some differences in types of mutations. Thus, a higher incidence of variability of the set of characters characterizing the potential of plant productivity was inherent in laser radiation, which is indicative of the prospects of using this new mutagen in breeding. We have yet to determine whether this is related to the pleiotropic effect of mutant genes, or to change in several segments of genetic material of the cell at the same time, or to other genetic mechanisms when plants are exposed to laser light.

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NEW BOOK ON LASER-RELATED INDUSTRIAL HYGIENE AND PREVENTION OF OCCUPATIONAL PATHOLOGY

Moscow GIGIYENA TRUDA I PROFESSIONAL'NYYE ZABOLEVANIYA in Russian No 8, Aug 82 pp 58-59

[Review by A. V. Bykhovskiy and V. A. Kashuba (Moscow) of book "Industrial Hygiene and Prevention of Occupational Pathology When Working With Lasers", by V. P. Zhokhov, A. A. Komarova, L. I. Maksimova, V. R. Muratov, Yu. P. Pal'tsev and A. I. Semenov, Moscow, Izdatel'stvo Meditsina, 1981, 208 pages]

[Text] Lasers have found broad application in different branches of science, technology and medicine. In accordance with the decisions of the 26th CPSU Congress, in the next 10 years there will be further qualitative and quantitative development of laser technology. This puts new tasks to medicine with regard to safeguarding the health of people servicing laser equipment.

Studies of the biological effects of the first lasers made it apparent that their radiation could present a hazard to personnel. It is not by chance that there are sections on hygiene, sanitation and safety practices when operating with lasers in a number of Soviet and foreign monographs that deal with biomedical and technical (M. F. Stel'makh; J. Reddy and others) aspects of the problem. The publication of the first Soviet monograph on problems of industrial hygiene and prevention of occupational diseases when working with lasers in the national economy is quite timely. It is needed by specialists who are in contact with laser equipment.

The monograph consists of an introduction, eight chapters, conclusion and appendix. The bibliography lists more than 100 titles by Soviet and foreign researchers. The book deals with a rather broad range of problems and some general issues--specifications of lasers, various areas of their application in the national economy, as well as hygienic and specific questions, including the mechanism of biological effects, distinctions of action of laser radiation on the eyes, integument and body as a whole, health status of individuals working with lasers.

It is significant that the authors make a differentiated evaluation of their findings in their comprehensive discussion of this multifaceted problem. Use of current experimental, physiological and clinical data enabled them to maintain that not only structural changes in irradiated tissues, but functional changes in the body must serve as a criterion of the adverse effects of lasers.

The essence of the problem is considerably revealed in the chapter on industrial hygiene when working with lasers, which is relatively small in size but is closely linked to data on dosimetry and setting hygienic standards of laser radiation. Data on evaluation of conditions and nature of work of operators and troubleshooters of laser units, analysis of actual situations that occur when operating many types of gas (helium-neon, carbon dioxide) and solid-state (neodymium, ruby) lasers for technological and therapeutic purposes, experimental and research work are of interest to readers. The distinct correlation between working conditions and biological effects of laser radiation, which was noted by the authors, is of hygienic importance. For example, it was established that when the work places have low levels of illumination the severity of effects of laser radiation may be enhanced due to substantial increase in size of the pupil and in sensitivity of the retina.

The chapter that contains clinical and physiological data on evaluation of health status of specialists servicing laser equipment is of particular interest. The authors maintain that, along with diverse functional changes, individuals servicing lasers could develop clinical sets of symptoms in the form of asthenic and asthenovegetative syndromes, as well as vegetovascular dysfunctions. Tables and other graphic data should have been provided in the book to back up these conclusions.

We consider it right that the authors laid emphasis on presentation of data on scientific validation of maximum permissible levels of laser radiation, which constitute an important part of optimization of working conditions. Their combined, methodologically validated approach to the problem permits setting more objective hygienic standards for laser radiation and creating more refined standards.

Group and personal protective gear is proposed by the authors among the measures aimed at improving working conditions for individuals involved with lasers. They discuss organizational, sanitary-technical, planning and other protective measures, and they offer a hygienic assessment of current types of goggles used as protection against lasers. It is important to mention that adoption of the hygienic recommendations listed in this book would be instrumental in optimizing working conditions for personnel servicing laser equipment.

No doubt, the book being reviewed is of scientific and practical interest for a wide range of specialists, and it is a definite contribution to the solution of the important hygienic problem of optimizing working conditions for individuals working with lasers. Obviously, this work cannot answer all of the questions pertaining to this problem. In this regard, we should like to mention some flaws, and voice several recommendations and wishes.

In our opinion, the surplus of material on biological effects of laser radiation leads to decrease in the necessary space for shedding light on purely hygienic aspects of the problem. Experimental material, as well as data on treatment of patients submitted to laser radiation and long-term results of such exposure, could have been an important addition to the book. Even now, this problem requires the use of systems analysis conceptions. Modeling such a system can disclose the mechanism of relationships between different elements of the system and would permit scientific validation of hygienic standards. It would have been interesting to compare data on evaluation of working conditions before and after adoption of hygienic recommendations, to provide photographs of safe laser equipment, as compared to equipment that does not meet hygienic requirements. We should like to recommend to the authors that the sphere of their attention include, along with firmly established data that have long since been used in practice, material on prognostic evaluation of laser equipment, particularly for the next 5-10 years and, in particular, with respect to lasers with changing wavelength, high-power and semiconductor lasers.

In spite of the few flaws which are not of basic significance and are more related to the novelty of the problem and difficulty of generalizing diverse material, this book, which was written by a team of authors, is assured a broad circle of readers. It is imperative to plan for another edition of this monograph, in view of the acute need for such literature (the book, printed in less than 1000 copies. immediately became a bibliographic rarity).

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USE OF LASERS IN HYGIENIC STUDIES

Moscow GIGIYENA I SANITARIYA in Russian No 7, Jul 82 (manuscript received 23 Nov 81) pp 55-58

[Article by V. A. Kashuba and M. A. Matyashova, Moscow Medical Stomatological Institute imeni N. A. Semashko]

[Text] Enormous attention is given to environmental protection in the proceedings of the 26th CPSU Congress. In the opinion of G. I. Sidorenko, academician of the USSR Academy of Medical Sciences, to solve this problem it is necessary to develop and refine the arsenal of modern methods of assaying chemical and biological pollutants of the atmosphere, water, soil and foodstuffs.

Basically new methods of monitoring and assessing the degree of pollution of the environment using various types of lasers could alter qualitatively and quantitatively the capabilities of services concerned with such problems (A. I. Melua; D. A. Ashkinadze et al.; I. M. Lipovskiy, 1977). Analysis of the literature indicates that new investigative methods in hygiene and ecology, which are based on the use of laser radiation, could find diverse applications under concrete practical conditions and field experiments, for example, for detection of diverse sources of pollution, monitoring them and implementing preventive measures. Moreover, lasers are an independent and valuable laboratory tool. Even now, using existing laser units and systems, as well as those in the process of design, it is possible to implement ongoing monitoring actually in three areas: quality of potable water, degree of purification of liquid sewage, pollution of seas and oceans, various layers of the atmosphere and soil (O. I. Abramov et al.; D. A. Ashkinadze et al.; N. F. Koshelev et al.; Hinkley et al.; Sato et al., and others). Interestingly, lasers that are an element of many technological processes, for example, processing hard ore [rock] and other hard materials, control of chemical reactions, have a much less adverse effect on the natural and industrial environment (V. A. Kashuba). As compared to existing ones, laser methods have several advantages: range, high precision, specificity, speed of readings (analysis of samples is made within fractions of a second); they are economical, fruitful, informative, and the data obtained with them can be readily processed on computers (D. A. Ashkinadze et al.; M. A. Kropotkin and Ye. G. Pashchenko; Melngeyist; Hinkley et al.). The difference in optical properties of clean and polluted environments--water, air, soil--is the physical basis of such methods of detection (V. V. Bogorodskiy and M. A. Kropotkin; E. G. Donchenko et al.; Ahmadjin et al.). Laser equipment is advancing from the stage of search of optimum methods, laboratory model studies and preliminary field trial (V. V. Bogorodskiy et al.; V. I. Epshteyn et al.). Laser locators (lidars) can be used from the shore, a spacecraft, aircraft, ship, motor vehicle, tall building and, moreover, at any time of day. The advantage of laser systems is that direct and reflected solar rays, change in ambient temperature, clouds and light fog do not have an effect on their operation (O. I. Abramov et al.; D. A. Ashkinadze et al.; V. V. Bogorodskiy et al., Meingeyist, Sheives et al.; Gross et al.). Turbulence of the sea is somewhat restrictive, but modern lasers can already operate at a turbulence of up to 5 (M. A. Kropotkin and Ye. G. Pashchenko).

There are several possible ways of remote detection of superficial water pollutants: by recording the intensity of laser radiation reflected from water or of excited fluorescent back-scatter of radiation, or by determining polarization of the reflected laser beam (O. I. Abramov et al.; V. V. Bogorodskiy and M. A. Kropotkin; Ahmadjin). Laser instruments (locators) have also been developed and are in use for remote detection of superficial oil pollutants [spills], the physicochemical and biological consequences of which are quite diverse and have a devastating effect on all elements of the biological chain.

With lasers (helium-cadmium, pulsed nitrogen, ruby, neodymium) one can determine not only the thickness of the film, its age, but distinguish between up to 28 types of oil products (O. I. Abramov et al.; M. A. Kropotkin and Ye. G. Pashchenko, V. V. Bogorodskiy et al.; Measurs and Briston). There is a promising system for the study of back-radiation from the marine environment, which can be used for detection of oil spills both during the day and night (M. A. Kropotkin and Ye. G. Pashchenko). Laser units can effect remote monitoring of gas and aerosol pollution of industrial and developing parts of cities, industrial centers, busy thoroughfares and parking lots. Virtually all of the hygienically important gases that pollute the atmosphere can be recorded, including those that are difficult to pick up, such as carbon monoxide and nitrogen, sulfur dioxide, ammonia and others (D. A. Ashkinadze et al., I. M. Lipovskiy et al., 1977; A. I. Melua; Hinkley et al.). The minimum levels that lasers are capable of detecting in the air environment are up to $2 \cdot 10^{-11}$. This permits very accurate determination of air pollution. For example, the demonstrable concentration of nitrous oxide in motor vehicle exhaust constitutes 10^{-5} mg/m^3, and dynamics thereof have been studied on a parking lot during the day at a distance of 500 m, at heights of up to 4.5 m (D. A. Ashkinadze et al.).

According to the data of Hinkley et al., modern laser systems can detect atomic sodium at an altitude of 90 km. A high-speed, highly effective laser analyzer of carbon dioxide was developed for the purpose of continuous studies and monitoring of variations in carbon dioxide background. Field tests have been performed on a Soviet unit for measurement of methane levels in the open atmosphere in Krasnoyarsk Kray and Yakutsk ASSR. Its sensitivity constitutes 0.01 million^{-1} with a probing range of 100 m. This unit is used not only for ongoing monitoring of carbon dioxide levels of industrial sites, but to inspect major gas lines for leaks, geochemical studies, exploration of gas and petroleum deposits in the tayga and swamps. This instrument was tested at the Ashkhabad seismic forecasting site in order to detect the gas precursors of earthquakes.

Atomic aerosol is one of the main factors that lead to change in climate conditions. With lasers, one can determine the concentration, type, distribution of industrial and natural aerosols in air (V. Ye. Zuyev; I. M. Lipovskiy et al., 1979; A. I. Melua; E. G. Donchenko et al.; Hinkley). Thus, part of the program for an international global aerosol experiment was performed in Tomsk. Laboratory laser units have been developed and introduced to practice for examining aerosols of diverse origin, which are formed in technological processes and detecting [or trapping] them in technological and ventilation exhaust (N. F. Koshelev et al.). A type LKA-2 laser unit was installed in the ventilation system duct of the composing shop of Moscow Printing House No 32 to monitor purification of exhaust from lead aerosol (V. I. Epshteyn et al.).

Lasers are used to study the dynamics of rapid atmospheric processes. Laser probing [sounding], which has become an independent direction, helps gain information about pressure, density, temperature, humidity, wind, clouds and other parameters of the atmosphere (V. Ye. Zuyev; V. M. Zakharov and O. K. Kostko).

Laser systems are more efficient, and they permit solving on a qualitatively new basis current hygienic problems related not only to detection of the source of hazardous pollutants, but expert evaluation of its role in polluting various environments, operational development of preventive tactics and measures. For example, laser units have been developed which immediately send a signal to an operator when permissible concentrations of discharge from smoke stacks are exceeded, they automatically provide for fuller combustion of fuel and in emergencies they turn off an entire system (Meingeyist; Hinkley et al.).

The results of laser-probing studies of the air basin of several cities in our country made it possible to propose a list of measures to improve it and to validate sanitary protective zones of enterprises (D. A. Ashkinadze et al.; A. I. Melua). By virtue of their unique properties, there may be new areas of application of lasers in various hygienic disciplines, microbiology and other branches of medicine and biology. Use of laser systems as a very precise laboratory tool, which is many times more sensitive than the usual methods of chemical analysis, is quite important to hygiene of nutrition and industrial hygiene, communal hygiene and toxicology. With the latest laser methods, one can study the spectra of chemical compounds, for example, one can identify and study vitamins, enzymes and other compounds and molecules in living biological objects, as well as root crops, fruit, leaves, without impairing their structure or processes. It is possible to study processes that occur in the retina of a functioning eye without causing side-effects (M. V. Yevdokimov et al.). The possibility cannot be ruled out that lasers will be used to assess the effects of pesticides and metals on biological activity of soil.

Thus, use of lasers in the field of hygiene makes it possible to effect a qualitative advance [jump], and to solve quite effectively biomedical and engineering problems of environmental protection, forecast possible changes in the environment, improve the sanitary and hygienic conditions of enterprises and cities, bodies of water, define a number of maximum permissible concentrations of deleterious substances and ultimately minimize the negative effect on many of adverse environmental factors.

No doubt, use of lasers to gain a large quantity of base data on an ongoing basis, generalization thereof with computers, development of special maps showing the relationship of existing concentrations of pollutants to the maximum permissible levels, development of automated (controlled) centers of urban environmental protection services will require new methodological studies, preparation and personnel training. The work of sanitary and epidemiological stations is becoming more sophisticated, preventive and routine sanitary surveillance is growing more effective, and this will definitely be instrumental in improving the people's living conditions.

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PUBLIC HEALTH

UKRAINIAN SCIENTISTS' CONTRIBUTION TO IMPLEMENTATION OF USSR FOOD PROGRAM

Kiev PRAVDA UKRAINY in Russian 10 Oct 82 p 2

[Article by P. Maystruk, doctor of medical sciences, director of the Kiev Scientific Research Institute of Hygiene of Nutrition: "Menus for Millions"]

> [Text] Implementation of the USSR Food Program will assure supplying the nation's population at the earliest possible time with all the necessary foodstuffs in accordance with hygienic standards. Special attention is being given to high-grade and biologically valuable products.
>
> The May plenum of the CPSU Central Committee indicated that science plays a significant role in implementing the Food Program. Of course, this applies primarily to the branches of science directly related to agroindustrial complex production. However, there are a considerable number of problems related to public nutrition that cannot be solved without us--scientists dealing with hygiene of nutrition.

The Kiev Scientific Research Institute of Hygiene of Nutrition is the leading one in our country in this field. We are submitting to fundamental development the scientific bases and hygienic standards of optimum nutrition for different age and occupational groups. For example, in recent years, studies were made of energy expended and nutrient requirements of workers in the metallurgic, mining, coal, machine-building, textile, chemical, confectionery and other sectors of industry, rural workers, vehicle drivers, teachers, scientific workers, children and other population groups. Summarization of these data made it possible to elaborate for the UkSSR Gosplan scientifically validated data on food requirements of this republic's inhabitants for the period up to 1990. They are taken into consideration in preparing the state plan for development of the national economy.

Concurrently, studies were pursued of diets in different climate and geographic zones of UkSSR. The largest sociohygienic study covered more than 30,000 people. It revealed that there have been substantial quantitative and qualitative changes in the diet of this republic's inhabitants in the last decades. There has been a significant increase in consumption of dairy products, butter, eggs, vegetables and fruit at the expense of some decrease in consumption of grain products and potatoes.

At the present time, the average caloric value of daily food intake per person is almost 15% higher than the optimum level. People are being warned about obestiy, adiposity and related cardiovascular diseases, cholelithiasis and urolithiasis, diseases of the digestive tract and joints, diabetes mellitus.... It is necessary to correct the diet by restricting the energy value of food (with monitoring of body weight) at the expense of foods of high caloric value, increased consumption of vegetable oil and low-calorie but biologically rather valuable products--vegetables, fruit, sour milk products, bakery goods made with coarsely ground flour.

As we know, animal proteins are among the most valuable and often deficient constituents of the diet. For this reason, the search and investigations, which are being conducted by this institute in cooperation with the Ukrainian Academy of Sciences and USSR ministries of the meat-dairy and fishing industry, of new resources for biologically valuable proteins, fuller and wiser use of resources of the meat and dairy industry, development of foods with higher nutrient value, are of special importance.

We are working seriously on the food resources of the oceans. We know of work on investigation of the nutritional value of the antarctic crustacean, the krill. It has been shown that krill is rich in proteins, whose value is not inferior to beef proteins. But, unlike the latter, it is richer in the essential polyunsaturated fatty acids, vitamins and minerals. For this reason, inclusion in the human diet of krill products--"Ocean" paste, krill oil and others--improves metabolism, enhances defense capabilities of the body with regard to toxic, infectious and other deleterious factors, and has a therapeutic effect on a number of diseases. The krill resources are tremendous. New valuable products can be recovered from it.

New sugar products are of great interest. Hundreds of biologically active substances are discarded with waste in the production of refined granulated sugar, while sugar consumption is growing. As a result, this beneficial and favorite product of people began to manifest the negative aspects of its effects. It has been given the role of risk factor in dental caries, atherosclerosis, diabetes and other diseases. The idea emerged of using a partially refined (intermediate) product--liquid sugar and powder from beets--for use for nutritional purposes, for example, in the confectionery industry. Aside from the hygienic and economic effect, this would increase significantly our nation's sugar resources by means of speedy processing of beet reserves, without expanding the production base. A new technological process is emerging in the food industry--powder technology. This is a process without any waste.

Development and hygienic evaluation of new specialized foods for pediatric, therapeutic and wise nutrition is important. They include canned fish for children ("Fish soup with quenelles," "Schoolchild's breakfast," "Fish souffle"), dairy beverages--"Aerin," "Smetanka," "Zhemchug" oil, "Gulliver" and "Malysh" sausage products for children, and others. Many of them have won certificates at the Exhibition of Achievements of the National Economy of UkSSR. In the last few years, 14 author certificates have been issued for new products, and for 23 others the standards and specification documentation have been elaborated.

Livestock farming is the key front of the Food Program. A key issue is to improve the quality of feed, particularly by increasing protein content, which would increase by 2-3 times animal productivity and would permit more economical outlay of grain resources. Several types of nitrogen-containing protein supplements have already been studied, which were proposed to replace part of the feed protein. In particular, a polymer has been recommended--carbamide. It provides for high-grade products (meat, milk) when used to replace up to one-third of the proteins in feed. At the same time, several protein supplements have been rejected due to the decline in meat and milk quality. Biomedical studies are in progress animal farming and poultry farming products obtained with use of feed antibiotics as growth stimulators. Vitamycin, kormarin and fradizin are good. Biomedical studies are also being made of the quality of livestock products obtained with use of stimulators.

Our goal is to have our projects adopted in the national economy, so that the plans of the party regarding solution of the food problem would be solved reliably and promptly on a high scientific level, in order to have the fare of Soviet people become richer and more abundant.

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DRUG SHORTAGE DUE TO MISMANAGEMENT OF PHARMACEUTICAL ADMINISTRATION

Frunze SOVETSKAYA KIRGIZIYA in Russian 22 Oct 82 p 2

[Article by A. Freydzon, nonstaff correspondent for SOVETSKAYA KIRGIZIYA, in the column "Products For the People: At the Factory, On the Counter": "Who Benefits From a Deficit?"]

> [Text] The health and life of man is cherished in our country as a most precious treasure. "Everything must be done," stressed Comrade L. I. Brezhnev at the 26th CPSU Congress, "so that Soviet man will always and everywhere be able to obtain modern and qualified medical assistance." A new indication of concern for the Soviet people was the resolution of the CPSU Central Committee and USSR Council of Ministers "Additional Measures for Improving the Health of the Population", which, along with other measures, indicated the need to assure the regular delivery of widely used medicines.

We go to the pharmacy in expectation of purchasing a drug which will alleviate an ailment and then to be free of it. Are our expectations always justified? Alas, not always, One knows this from personal experience and the complaints that people leave at pharmacies or send to the Pharmaceutical Main Administration (PMA), the republic Ministry of Health and to other levels. Perhaps these complaints refer to certain extremely rare drugs that cannot possibly be provided to all that need them? Or to the latest preparations, whose regular production has not yet been organized? Nothing of the sort. People are justly angered by the fact that it is sometimes impossible to purchase at pharmacies common medicines that have long been familiar, such as nitroglycerin, valocardin, erinit, korvalol, and finally, mustard plasters. What happens to heart patients in these situations I think need not be told. Other drugs are also sold with interruptions; moreover, these are drugs that are required by thousands of patients. You may satisfy yourself of this by visiting pharmacies Nos. 1, 2, 38, 55, 111 and 240 in Frunze.

Here is what S. Chinshaylo, the manager of pharmacy No 240, says on this issue:

"From September 1981 to the present the pharmacies have lacked many cardiac preparations--nitroglycerin, tselonid, digoxin and erinit. True, 100-200 packages of nitroglycerin were delivered during January-February of the current year. But this is a drop in the ocean. In the autumn and spring during an outbreak of catarrhal diseases we could not meet the demand for bisseptol, sulfadimidine and many antibiotics. For a long time we have not received potassium permanganate, ammonium hydroxide, pepper plaster and medicinal herbs."

Roughly the same was heard from workers at other pharmacies.

Not having found the necessary drug at one pharmacy, people set out to others. Most frequently to pharmacy No 1, not so much in expectation of acquiring the drug as to determine at the information bureau where it can be found. Having stood sufficiently long in line, a person finally elbows his way to the window. The employee takes his prescription and, as a rule, begins calling up pharmacies (the pharmacies themselves, it turns out, by no means always report the availability of drugs, particularly scarce ones). In general considerable time is spent, quite often to hear: "The drug is not available." Recently still another information bureau was opened in the city at pharmacy No 237, in the sixth microrayon. Thus it has become easier to obtain the information that "The drug is not available."

Of course, it on this basis that such complaints arise as:

"I am angry that for three to four months there have been no nitroglycerin, valocardin or Zelenin's drops at the pharmacy," says N. Poletayev, a participant in the Great Patriotic War.

The following is a reply to the verteran's complaint from the head of the commercial department of the Pharmaceutical Main Administration, V. Mukhamedziyev: "The interruptions are explained by a disruption in the delivery of nitroglycerin and inadequate satisfaction of the demand for valocardin. At the present time nitroglycerin, korvalol and valocardin have been released to the pharmacies. The order for nitroglycerin has been increased, which will permit an uninterrupted supply to patients."

One who does not know theetrue situation may be impressed to say: "Look how sympathetically they respond to the workers' complaints." But do not jump to conclusions. As a cross-check revealed, the answer cited here is nothing more than a standard reply.

To demonstrate this we shall examine some data: according to the acoounts of the PMA the order for 55,000 packages of nitroglycerin was fully met during the past year. In each of the first and second quarters 12,500 packages were delivered and in each of the third and fourth quarters, 15,000 (excepting Osh Oblast). Thus we see that there was no disruption in the nitroglycerin deliveries!

Furthermore, on 1 January there were 17,027 packages at the central PMA warehouse, which is 2,027 units more than was obtained during the fourth quarter and almost sixfold greater than the permissible reserve.

Nor were the nitroglycerin deliveries disrupted during the current year. In accordance with the order for nitroglycerin, considerably more--70,000 packages--was allocated to the republic than during the past year. A delivery of 15,000 packages was planned during the first quarter, and the entire quantity was obtained in February. Throughout this time the warehouse stores of this medicine were four- to fivefold greater than the permissible norms and were uselessly high: 11,200 packages on 1 February and 15,800 packages on 1 March. And during this time N. Toletayev was exhausting himself in his search for the drug.

The story is the same with valokardin. The stocks allocated for 1981-1982 fully met the orders. They were even issued in excess. Thus, 90,000 flasks were allocated to the republic (without Osh Oblast) in 1981 and 90,780 were received. The remainders at the warehouse also exceeded the norm by 11-fold according to the situation on 1 January of the current year and by 6-fold on 10 March. Such were the conditions created at the end of the past and the start of the current year. An acute deficit developed when it should not have.

There are not many of the aforementioned drugs at pharmacies even to this day. Who is to blame for the fact that patients leave the pharmacies empty-handed, while the drugs they need gather dust on the shelves of the central pharmaceutical warehouse?

In the first place the commercial department, headed by Comrade Mukhamedziyev and which consistently impedes distribution to the pharmacies. Perhaps the department's workload is high? People lack the time to meet their responsibilities? Nothing of the sort. More than a year ago a sales department was established, which was entrusted with drug distribution and sale. For his own department Comrade Mukhamedziyev left only the distribution of prescription drugs. However, the situation changed little. The drugs sometimes sit long at the warehouse and reach the pharmacies only when there remains only a month or a month and a half before the expiration date. Take lidaza. It is shipped to Frunze by air so that less time is lost in transport. And it sat at the warehouse for eight months, while it has a 12 month expiration date.

Such procedures inflict double damage. On the one hand, economic. Sometimes more than a million rubles are frozen in the warehouse drug reserves. And how to measure the damage from the fact that an ill person did not find a needed drug at the pharmacy?

One would think that the Ministry of Health could find the means for organizing such an important matter as the uninterrupted provision of the population with medicines.

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PHARMACOLOGICAL AGENTS DERIVED FROM UNDERWATER ORGANISMS

Moscow TRUD in Russian 25 Aug 82 p 3

[Article by V. Stonik, head of Biosynthesis Laboratory, Pacific Ocean Institute of Bioorganic Chemistry, Vladivostok: "Scientific Research--Underwater Pharmacy"]

> [Text] In March of this year, numerous specimens of underwater inhabitants of the tropical zone of the Indian Ocean appeared in laboratories of the Pacific Ocean Institute of Bioorganic Chemistry, Far-East Research Center of the USSR Academy of Sciences. Research is continuing there on physiologically active substances of marine organisms, which was started aboard the "Professor Bogorov" research ship that returned from a 4-month voyage to the shores of Madagascar, Tanzania and the People's Democratic Republic of Yemen.

It has been long known that drugs can be recovered from certain algae and marine animals. However, it is only very recently that they began to be used in medical practice. For example, red algae broth was used since antiquity in folk medicine of Southeast Asia for treatment of various diseases. They contain a potent antihelminthic, digenic acid. Marine worms--Polychaeta--are excellent fish bait. Then it was noticed that insects that light on such worms die rapidly. Investigation of this phenomenon resulted in the discovery of a substance that is highly toxic to agricultural pests--nereistoxin. There is a synthetic insecticide, so-called padan, with structure similar to nereistoxin, that is highly effective as protection against insects, not hazardous to warm-blooded animals and it does not accumulate in soil or foodstuffs, unlike ill-reputed DDT.

Drawings of blowfish [puffers] have been found on the walls of the Egyptian pyramids. In Japan, they are known under the name of "fugu" and they are considered a delicacy. Dishes with fugu can be prepared only in special restaurants and only by cooks who have a license. This is related to the fact that the roe and viscera of this fish contain a lethal substance. Still, in spite of the precautions, dozens of Japanese die each year of fugu poisoning. Scientists began to study this fish and found that tetrodotoxin, which was isolated in pure form from its roe, has anesthetic properties, even in very low concentrations, and it is thousands of times superior to the well-known cocaine.

Such very promising discoveries are made annually in different laboratories of the world. For example, it has been reported that products from the mollusk, Mercenarium, and the tentacles of certain Polychaeta cured laboratory animals with experimental tumors. Unusually high concentrations of prostaglandins were discovered in a number of soft and gorgonian corals, which had previously been found in very small amounts in the mammalian prostate. These hormones have anti-asthmatic action, lower blood pressure and exhibit a number of other valuable properties. Some scientists call them drugs of the 21st century.

What has prompted the interest in marine organisms on the part of bioorganic chemistry? The structure and functions of ocean inhabitants are often unique. Studies of one of the sponges from the Caribbean Sea resulted in recovery of unique chemicals--arabinouridine and arabinothymidine. Synthesis of their analogues helped develop an antineoplastic drug, arabinocytosine. Another product referable to the same series demonstrated high efficacy in the treatment of encephalitis.

To what do scientists attribute such unique properties of ocean life? In the course of millions of years of development, marine animals and plants produced hundreds of different compounds that protect them against pathogenic microorganisms. Their unusual living conditions were instrumental in development of unique structures and properties. It is a difficult and expensive task to define and discover them, to make them serve mankind. According to estimates made by specialists, it costs 5 million dollars to develop a new drug against cancer that is based on substances recovered from marine animals.

Because of technical difficulties, intensive investigation of the ocean's pharmacy only started in the last 20-30 years. This is attributable to the fact that, for a long time, there was no reliable equipment to study underwater life. Appearance of aqualungs and high-power spectral technology eliminated this problem. Research ships were constructed and outfitted with excellent laboratories. They have a vivarium with a large number of experimental animals, and this permits experimentation and obtaining preliminary data right at sea.

At present, we can already speak of the definite advances of marine bioorganic chemistry. Our Pacific Ocean Institute is the executor of an international scientific program for the search of cancer drugs. Mollusks and corals have become the basis for agents with anticarcinogenic activity.

The question is sometimes asked: Would not the attention given by scientists to the pharmacological wealth of the oceans disrupt the ecological balance among its inhabitants?

We think that such alarm is unjustified. There are about 200,000 species of animals and plants in the seas and oceans. Mankind, however, only uses a small part of them for its needs. It should also be borne in mind that, because of flaws in technology of processing marine products, thousands of tons thereof are referable to waste. We refer to the shells of crustaceans, fish heads and viscera. Yet they could be valuable raw material for production of biologicals and drugs. One can recover polysaccharides from algae, which are of interest not only to the food industry, but medicine. The salts of one of these polysaccharides, alginic acid, removes heavy metals, for example, strontium, from the body. They can be used to treat certain types of poisoning.

The study of the structure of physiologically active substances contained in marine organisms, investigation of the mechanism of their action and, finally, synthesis of these compounds and their analogues--such is the task that will make an exceptionally large contribution to science and practice.

We know that the most interesting discoveries are presently made on the boundary between different branches of science. Is marine bioorganic chemistry an exception? To some extent it is not. It was noted that so-called signaling substances play an extremely important part in the life of underwater organisms. Some of them in amazingly small doses help males and females find one another in the boundless ocean. Others warn them of danger, and others yet enable larvae to find places that are comfortable for subsequent development. It is very interesting to study signaling substances from the standpoint of controlling the behavior of marine animals at underwater plantations, which already exist off the coast of the Maritime Kray. But, it was also found that these substances often have various therapeutic effects: antifungal, antineoplastic and others. Thus, they can be used in the search for new biologicals.

On today's agenda is the question of broad utilization of the biological resources of the ocean. And this new sector should be created through the joint efforts of scientists and clinicians referable to different specialties. Only then will drugs from the ocean become part of our life with full rights in the very near future.

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EVALUATION OF SIGNIFICANCE OF PARAMETERS OF FUNCTIONAL ACTIVITY OF ADRENAL CORTEX TO FORECASTING INDIVIDUAL RADIOSENSITIVITY, REPORT 1: METHODOLOGICAL APPROACHES TO FORECASTING INDIVIDUAL RADIOSENSITIVITY ACCORDING TO INDIRECT PARAMETER OF ADRENOCORTICAL ACTIVITY

Moscow RADIOBIOLOGIYA in Russian Vol 21, No 1, Jan-Feb 81 (manuscript received 30 Mar 80) pp 86-89

[Article by N. G. Darenskaya, A. O. Korotkevich and V. M. Yezhova]

[Text] Male Wistar rats weighing 227±6.4 g were used to investigate the possibility of predicting the outcome of radiation sickness on the basis of derivative parameters of K/Na ratio in whole blood before and after irradiation by the method of parabolic distribution and Gaussian type distribution. It was shown that use of Gaussian type distribution permitted forecasting the outcome of radiation sickness according to K/Na parameters in blood, with maximum accuracy of 89%.

Various parameters of base state of the organism (leukocyte and erythrocyte counts, fluid and oxygen uptake, carbon dioxide output, rate of weight gain, blood proteinase activity, urine K/Na ratio) have been used to characterize individual radiosensitivity [1-4]. A parabolic function was established for most parameters; specimens with average parameter values manifested the most radioresistance. For determination of correlation between radiosensitivity and different parameters, the method of correlative relations [5], ranking principle [3], as well as polygon of frequencies of Student's *t* criterion for parameters of animals that died and survived [1, 6, 7] were used. Considering the important part of the adrenal cortex in formation of individual constitutional reactivity, an effort was made at a quantitative evaluation of rat death on the basis of an indirect parameter of adrenocortical activity--K/Na concentration in blood.

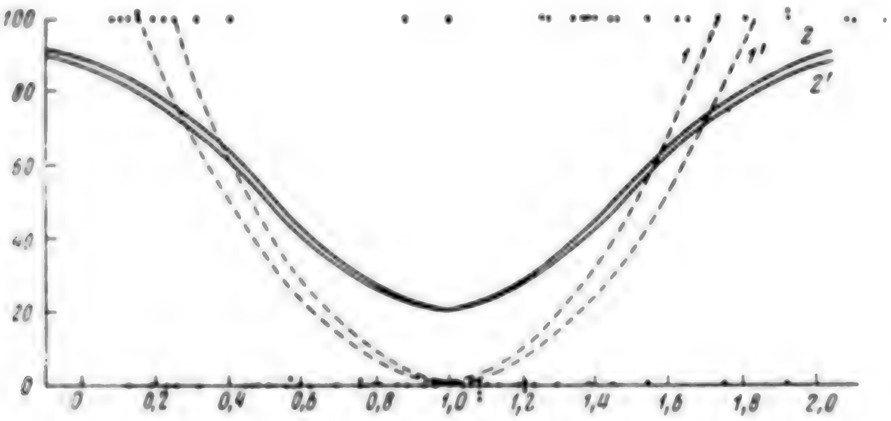
Material and Methods

Experiments were conducted on 125 male Wistar rats with initial weight of 138±6.8 g and, at the time of irradiation 227±6.4 g. The "learning" sample consisted of 69 rats, the outcome of radiation sickness was predicted for 56 rats. We assessed adrenocortical activity according to K and Na ratio in whole blood. Blood was taken for tests from the caudal vein, twice before irradiation at a 1-week interval and 2 h after exposure. K and Na concentrations were assayed by flame spectrophotometry [8].

In the morning, the animals were exposed to ^{60}Co γ-radiation in a dosage of 206.4 mC/kg (800 R) for the "learning" sample and 219.3 mC/kg (850 R) for the control experiment at dose rates of 0.557-0.488 mA/kg (129.6-113.6 R/min). Several parameters were calculated to determine adrenocortical activity: we determined initial adrenocortical activity (A_m) from the results of two tests before irradiation, and assessed lability of the system according to difference between the first and second tests (A_1-A_2), while the system's reaction to irradiation was assessed from the difference between K/Na ratio in blood 2 h after exposure and the base level (A_{irr}-A_m).

Results and Discussion

Mortality among animals exposed to a dosage of 206.4 mC/kg constituted a mean of 40% and after a dosage of 219.3 mC/kg, 71%. The animals died between the 3d and 29th days. Analysis of K and Na concentrations in whole blood and ratio between them before and after irradiation (Table 1) impressed us by the marked individual differences. There were also considerable differences in K/Na in different experiments, apparently due to seasonal variability. For example, minimal value was observed in February (0.87) and maximal in May (1.44). We found an increase in electrolyte concentration in whole blood 2 h after irradiation. There was greater increase in Na concentration, which led to an average 11.7% decline of the coefficient (3.6-19.6%). In order to increase the "learning" sample, we calculated the reduced value of parameters (quotient of value of parameter for a given animal divided by the mean-group value), which enabled us to combine data from different experiments.



Curves of probability of rat death as a function of postradiation change in K/Na. X-axis, reduced blood K/Na according to parameter of reaction to radiation--A_m; y-axis, probability of death. The dots show values of parameters in individual animals

1, 1') parabolic distribution	1, 2) for "learning" sample
2, 2') Gaussian distribution	1',2') for control experiment

If the experimental points are plotted in such a manner as to have the parameter values for surviving animals situated on the axis of zero probability of death and those of animals that died on the axis of 100% probability of

Table 1. K and Na content (mg/mℓ) and ratio thereof in rat blood before and after irradiation

Animal group & dosage, mC/kg	Season	Number of rats	Deaths %	A_1			A_2			2 h after irradiation		
				K	Na	K/Na	K	Na	K/Na	K	Na	K/Na
Learning sample, 206.4	Oct	24	42	2,15 1,82—2.7	2,28 1,66—2,84	0,96 0,79—1,3	2,14 1,9—2,35	2,17 1,75—2,35	0,99 0,81—1,27	2,35 1,68—3,38	2,66 1,75—3,76	0,89 0,65—1.16
	Feb	10	40	2,06 1,82—2,35	2,30 2,0—3,05	0,87 0,76—0,91	1,87 1,52—2,6	1,96 1,38—2,95	0,98 0,68—1,26	2,13 1,9—2,35	2,97 1,88—4,38	0,77 0,41—1,17
	Apr	10	40	1,85 1,6—2,25	1,5 1,34—1,95	1,26 0,85—1,41	1,92 1,8—2,3	1,34 1,2—1,58	1,44 1,14—1,58	1,9 1,7—2,25	1,69 1,3—2,53	1,16 0,89—1,38
	May	25	36	2,09 1,75—2,5	1,56 1,25—2,07	1,35 1,08—1,92	2,1 1,85—2,65	1,96 1,68—2,29	1,04 0,87—1,33	2,02 1,82—2,3	1,94 1,6—2,93	1,06 0,75—1,31
Control exper. for forecast 219.3	Nov	27	70	2,12 1,6—2,85	2,06 1,29—3,5	1,07 0,6—1,51	2,18 1,24—2,94	1,9 1,05—3,08	1,18 0,73—1,65	2,01 1,65—2,5	2,39 1,51—4,44	0,9 0,45—1,4
	Jul	29	72	2,5 1,95—2,85	2,0 1,55—2,28	1,25 1,01—1,35	2,52 2,01—2,94	1,97 1,45—2,8	1,29 1,14—1,55	2,39 1,85—2,5	2,15 1,35—2,79	1,18 0,86—1,6

death (Figure), to describe them we can use a parabola, the apex of which, corresponding to zero probability of death, will be situated at the point of the mean value of the parameter:

$$P = a(x_i - \overline{x})^2 \qquad (1)$$

where P is probability of death, %, a is the coefficient of a quadratic equation, x_i is the parameter for a given animal and $\overline{x}$ is the mean-group value of the parameter. Coefficient a was calculated by the least squares method [9]. The curve of probability of rat death as a function of change in K/Na after irradiation is illustrated in the Figure (curve 1). Analogous curves were plotted for all other parameters. The equations for the curves are listed in Table 2 [neither Table 2 nor Table 3 is provided with original article].

Substituting the value of the parameter for a given animal in equation (1), we can calculate the probability of its death as a function of value of the parameter. Table 3 shows the accuracy of coincidence obtained for different parameters and aggregate thereof. As can be seen in the Figure and Table 3, the parabolic curve does not cover all animals: some of them, those with very low or very high values for the parameter, are not taken into consideration for the prognosis. For this reason, to describe the probability of death of all animals, including those with extreme values for the parameters, we used the formula for normal Gaussian distribution (Figure, curve 2), which can be modified in the following manner to apply to our case:

$$P = 100\% - A\cdot e^{-\beta\frac{(x_i-\bar{x})^2}{\bar{x}^2}},$$

where P is probability of death, %, A is survival rate in the group of animals with average values for the parameter, e is the base of the natural logarithm, β is a numerical coefficient characterizing the divergence of branches of curves, x_i is the value of the parameter in a given animal, $\bar{x}$ is mean-group value of the parameter. Equations for the curves of probability of rat death as a function of value of different parameters are given in Table 2. [No Table 2 or 3 in article.]

Applying the law of normal distribution enabled us to increase the accuracy of coincidence of calculated probability with outcome of radiation sickness from 55-73 to 58-78% (Table 3), which is apparently attributable to the use of a more correct method of distribution and consideration of all animals, including those with extreme values for the parameters.

We used the obtained coefficients of curves to predict the outcome of radiation sickness in 56 rats exposed to radiation in a dosage of 219.3 mC/kg. Forecasting the outcome of radiation sickness on the basis of parameters of blood K/Na by the method of parabolic distribution does not yield a very accurate (37-64%) forecast of the outcome of radiation sickness in the rats; however, use of Gaussian type distribution enabled us to more accurately (48-89%) predict the outcome of radiation sickness. The coefficients used for forecasting were checked by plotting the corresponding distributions on the basis of the final results in the control experiment, by comparing them to the coefficients for the learning sample. The accuracy of coincidence in constructing these distributions (Table 3) is close to the accuracy obtained in forecasting, which is confirmed by the calculated coefficients (Table 2) and location of the curves (Figure, curves 1' and 2').

Thus, use of parameters of an indirect indicator of adrenocortical activity--whole blood K/Na ratio--enabled us to predict with rather high accuracy the outcome of radiation sickness in rats. The most accurate prognosis was obtained with use of normal Gaussian distribution. The accuracy of the forecast obtained in our experiments on the basis of this parameter was the same or somewhat greater than the accuracy of prognosis made by other authors who used different methods for an aggregate of parameters [1, 3, 5-7].

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PRESSING PROBLEMS OF RADIOECOLOGY IN LIGHT OF SOLVING ATOMIC ENERGY PROBLEMS

Moscow RADIOBIOLOGIYA in Russian Vol 21, No 1, Jan-Feb 81 (manuscript received 19 Sep 80) pp 97-108

[Article by R. M. Aleksakhin and G. G. Polikarpov, All-Union Scientific Research Institute of Agricultural Radiology, USSR Ministry of Agriculture, Obninsk, and Institute of South Seas Biology imeni A. O. Kovalevskiy, Ukrainian Academy of Sciences, Sevastopol]

[Text] The main tasks are outlined for modern radioecology in the area of migration of natural and artificial radionuclides, effects of ionizing radiation on natural biogeocenoses in connection with development of atomic energy. There is discussion of problems of setting ecological standards for radiation effects on ecosystems, and a classification is offered for natural zones according to criterion of radioecological condition. Emphasis is laid on the importance of studies of migration into the biosphere of "radionuclides of the complete nuclear fuel turnover."

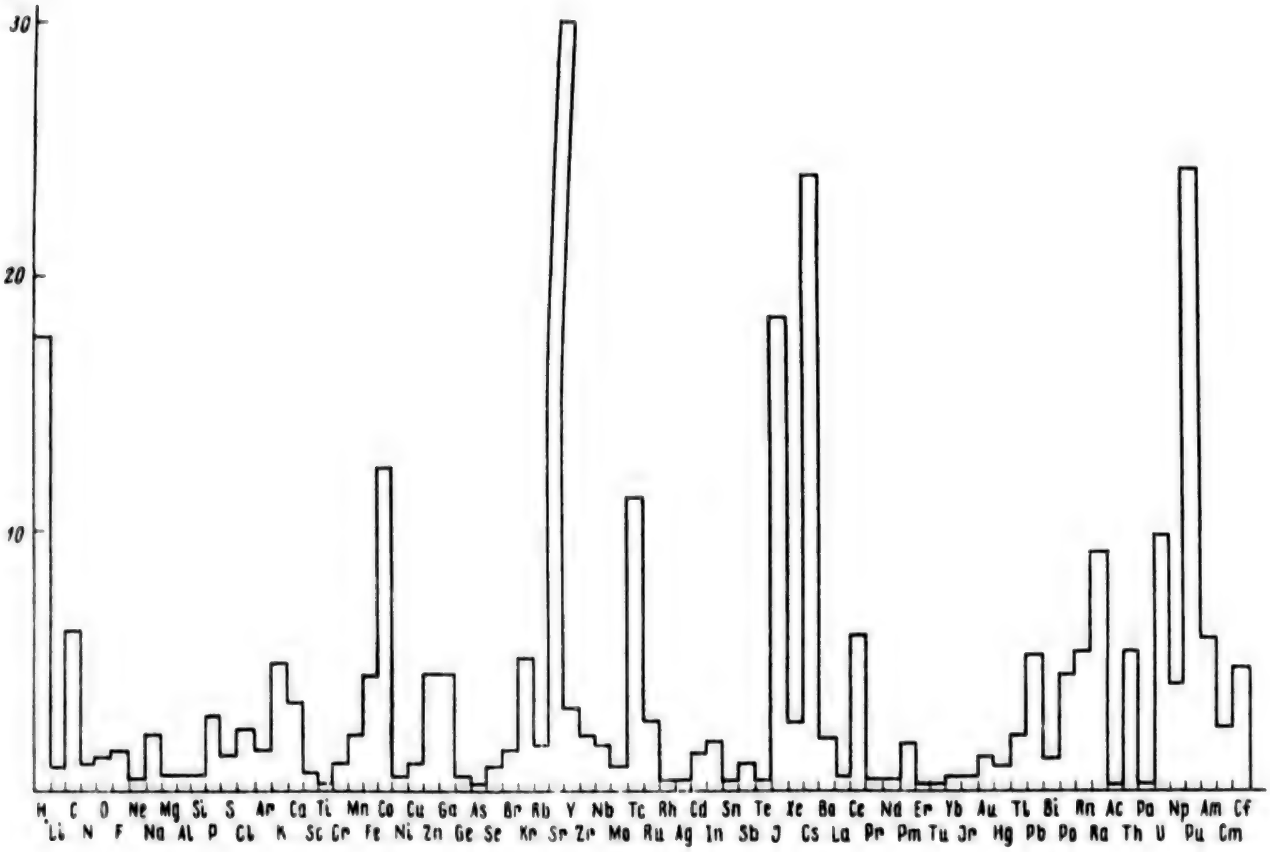
Radioecology was conceived as a science in the 1930's, when radiation changes were discovered in living organisms under the effect of rise in natural background of ionizing radiation (at the sites of radioactive ore deposits). The sources of the ecological approach to studies of biological effects of external radiation and distribution of radionuclides (in modern terminology) in the biosphere date back to the turn of the century and even the end of the 19th century. Thus, in the pioneer work by I. R. Tarkhanov [1], performed in 1896, i.e., right after the discovery of x-rays in 1895, an effort was made to use various representatives of the marine fauna (frogs, minnow roe) and flora (algae) for comparative studies. Concentration of radionuclides in elements of marine biogeocenoses also started to be determined soon after discovery of the phenomenon of natural radioactivity in 1896. The work of the school of Academician V. I. Vernadskiy in the area of biogeochemistry of radionuclides was particularly fruitful, and it served as the chemical basis of radioecology.

However, intensive development of radioecological research is referable to the late 1940's and early 1950's. Expressly in this period, ionizing radiation (including the anthropogenic component of the natural radiation background resulting from human endeavor in the area of developing atomic energy) gained recognition as one of the most important environmental factors. The broad interest in problems referable to the effects of ionizing radiation on the environment in those years was attributable primarily to the global rise of natural radiation background due to fallout of artificial radionuclides following nuclear tests. In particular, formation of the Scientific Committee on the Effects of Atomic Radiation (SCEAR) by special decision of the UN General Assembly in 1955 was a reflection of this increased attention to problems of increasing the radiation burden on living organisms; one of its main tasks was to assess and analyze changes in the radiation conditions on our planet resulting from human endeavor. In more than 25 years of operation of the UN SCEAR, a large part of its work consisted of surveying and submitting to critical analysis the ecological aspects of migration of radionuclides in the environment, and effects of ionizing radiation on living organisms and man. Another example of the concern of different nations in solving problems of radioecology on the level of international organizations is the creation, by decision of the IAEA, of a specialized International Laboratory of Marine Radioactivity in 1961, in Monaco, whose tasks include not only scientific research, but as a service for intercalibration of radiological measurements involving dozens of national laboratories of different countries, including the USSR.

At the present time, radioecology has gained another powerful impetus for development, which is related to the intensive conversion of the energy base of progressive nations of the world to a nuclear foundation. As we know, at all stages of the complete nuclear-power fuel cycle [turnover](mining for uranium, metallurgical processing thereof, production of fuel-emitting elements for reactors, radiochemical processing of irradiated fuel to isolate plutonium, storage and burial of radioactive waste) there is discharge into the biosphere of a specific (strictly monitored) amount of radioactive substances. Assessment of the consequences of migration of radionuclides into the environment as a result of conversion to nuclear power constitutes the central task for modern radioecology.

Among the artificial radionuclides, migration of which into the environment is related to the nuclear power fuel cycle, the leading place is occupied by the group of long-lived radionuclides, ^{3}H, ^{14}C, ^{85}Kr, ^{129}I, ^{239}Pu and several others. Appearance in the biosphere of high amounts of these radionuclides, many of which have considerable biogenic activity, is of considerable interest, since the highest dose burdens estimated over a long range are linked with them and, consequently, so are the potentially most important radiological sequelae.

While attention was focused mainly to analysis of behavior in the environment of such radionuclides as ^{90}Sr, ^{137}Cs and other radioactive fission products, along with certain nuclides with induced activity (i.e., the main components of global radioactive fallout), in radioecological studies of the 1950's and 1960's, at the present time interest has shifted in radioecology in the direction of studying the behavior in the biosphere of so-called "radionuclides of the nuclear fuel-energy cycle." Such artificial radionuclides as ^{239}Pu, ^{129}I, ^{3}H and transuranium elements (Np, Am, Cm) have become the leaders in current radioecological and radiobiological research, along with the traditionally studied long-lived radioactive fission products, ^{90}Sr and ^{137}Cs. This is evident from the Figure, which was based on analysis of a block of data consisting of 13,240 sources of Soviet and foreign publications published in 1977-1979 in the abstract journal, RADIATSIONNAYA BIOLOGIYA [Radiation Biology] published by the All-Union Institute of Scientific and Technical Information. At the present time, there is intensive accumulation of ecological data on migration in the environment of these radionuclides and patterns of their metabolism in living organisms.



Distribution of publications referable to worldwide radiobiological and radioecological literature including studies of behavior and migration of different radionuclides in 1977-1979. X-axis, elements in the D. I. Mendeleyev periodic table; y-axis, frequency of publications, relative units

The persisting interest in behavior in the biosphere of radioactive fission products--components of global fallout (primarily ^{90}Sr and ^{137}Cs)--is attributable to the need to assess the patterns of transfer of these radionuclides over biological and food changes in the long-range aspect, considering that, on the one hand, their mobility in the environment and accessibility to plants and animals could change as time passes and, on the other hand, that ^{90}Sr and ^{137}Cs continue to be important dose-forming sources among the assortment of natural radionuclides discharged into the biosphere, which continue to migrate into it. Moreover, ^{90}Sr and ^{137}Cs are among the constituents of radioactive waste.

The Figure also shows that natural radionuclides in the uranium and thorium families (^{238}U, ^{232}Th, ^{226}Ra, ^{222}Rn, ^{210}Po, ^{210}Pb and others) constitute another group of radioactive substances, to which modern radiobiology and radioecology is paying attention. Production of energy on a nuclear basis leads to discharge into the environment (at the stages of recovery of raw materials and primary processing thereof) of increased amounts of heavy natural radionuclides. In addition, there are several areas of human endeavor (use of chemistry in agriculture including mineral fertilizers with high levels of natural radionuclides, use of construction materials containing high concentrations of these radionuclides, etc.) that are also involved with discharge into the environment of this group of radioactive substances and intensification of the natural radiation background. The regular occurrence of international symposiums dealing with this problem [2, 3] is a reflection of the growing interest in the effects of the increased natural radiation background on living organisms referable to natural radionuclides and in questions of circulation of natural radionuclides in the biosphere.

Thus, in the area of investigation of patterns of migration of radioactive substances in the biosphere, among the first and foremost goals is to obtain experimental data on quantitative parameters of transfer of the nuclides that are the most relevant to the nuclear-energy fuel cycle. We still do not have sufficient radioecological information of this kind for this group of nuclides to make a satisfactory assessment of the consequences of their appearance in the biosphere. Along with gathering experimental data on migration of these radionuclides over biological and food chains, it is imperative to undertake development of time and space models of transport thereof for different biogeocenoses or for the most important routes of transfer of radionuclides from the environment to living organisms and man. The example for such models could be the designs made for ^{131}I and ^{137}Cs based on principles expounded in Publication No 29 of ICRB [International Commission for Radiological Protection] [4], with use of static (method of coefficients of concentration) and dynamic (systems analysis method) principles.

Disposal [burial] of radioactive waste--the key task in protecting the biosphere during intensive development of nuclear energy--occupies a special place in the problem of migration of radionuclides in the environment, and overall progress in converting the energy base to a nuclear foundation depends on solving it. New, previously unknown problems confront radioecology in this direction. The fact of the matter is that the main constituents of such waste are long-lived artificial radionuclides of neptunium, plutonium and transplutonium elements, whose half-lives constitute thousands and tens of thousands of years. Forecasting their migration into the environment should yield information about the time and space migration of these long-lived radionuclides for many hundreds of years. Today's radioecology has models of transfer into the environment of radionuclides with half-lives only of several tens of years at most. For this reason, radioecology must develop basically new approaches to development of forecasting models of transfer of long-lived radionuclides at the very end of D. I. Mendeleyev's period table with consideration of long-term (hundreds, thousands of years) processes of migration in various natural environments (soil, water, etc.).

In this area of radioecology, our attention is drawn to deep-water radioecology, which is being developed intensively in connection with investigation of the conception of United States scientists of the possibility of burying highly radioactive waste very deep in the ocean [5]. In this respect, there is not enough information about the specifics of conditions in the ocean deep: very little study of animal and microbial population of benthonic sediments and near-bottom layers of water, little data on behavior of ^{99}Tc, ^{237}Np, ^{126}Sn, ^{129}I and other radionuclides on the ocean bed and adjacent deep layers of water, numerous flaws in models simulating the consequences of dumping highly radioactive waste in the ocean. A recently published book by French authors, "Marine Radioecology" [6], reports on many years of dumping mildly radioactive liquid waste from nuclear plants in La Hague into waters of La Manche* andecological studies of migration of removed radionuclides in the coastal water environment, with participation of marine plants and animals.

Considerable studies are being conducted in radioecology of the Baltic and Black Seas (including those along the lines of CEMA), international waters adjacent to the estuary of the Danube River and the Danube itself [7, 8]. In a recent report [9], there is a description of an instructive pattern of change in concentrations of ^{90}Sr in water and hydrobionts of the Danube estuary from 1960 to the present. The drastic reduction of migration of artificial radionuclides into the environment after nuclear testing, in connection with the Moscow Agreement of 1963, was associated after several years with decrease in radionuclide concentration in waters of the estuary and then, with passage of time, in waters of the Black Sea. Fish and algae follow the same pattern with a dynamic lag. Interestingly, in recent years the concentration of ^{90}Sr in Danube River water became lower than in the Black Sea, and at present the Danube does not pollute the Black Sea with ^{90}Sr, but dilutes it. The instructiveness of this pattern consists of the fact that, apparently, any large-scale contamination will undergo the same attenuation, leading to restoration of purity of ecosystems, upon eradication or limitation of the source of pollution by toxic substances, mechanical suspension, surplus of biogenic elements, organic compounds, etc. In this respect, conceptions about the biogeocenological mechanism of removal of radioactive and chemical pollutants from the photic layer of seas and oceans, which is determined by the magnitude of primary phytoplankton production, are being developed in the Department of Radiation and Chemical Biology, Institute of South Seas Biology imeni A. O. Kovalevskiy, Ukrainian Academy of Sciences. In other words, it is becoming possible to assess and predict the maximum rate of migration of pollutants into this extremely important layer of the oceans, which is inhabited by pelagic algae, i.e., determination of the ecological capacity of this ecosystem for foreign or natural substances present in excessive amounts.

The second focal task for radioecology is the study of biological effects of ionizing radiation on the population and biogeocenotic levels. Considering the growth of nuclear power, radioecology is faced with tasks of assessing radiation effects of a wide range of doses, from acute and subacute (simulation of accidents) to small and ultrasmall (analysis of sequelae of global dissipation of radionuclides and worldwide increase in natural radiation background).

It is a difficult experimental task to investigate the effects of low radiation doses under natural conditions (in radioecology, low doses should be

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construed as chronic exposure to doses in the range of up to 0.1-0.3 Gy/year). As a rule, such experiments are conducted in a natural environment, with naturally or technogenically increased concentrations of natural or artificial radionuclides. Some parts of Komi ASSR could be one of the examples of such regions, where the levels of heavy natural radionuclides (uranium, thorium, radium and products of their decay) are elevated due to man's technogenic activities or natural causes. A summary of the results of studies referable to recent years in this region [10-15] revealed that noticeable changes are occurring in populations of living organisms on different levels with doses of external radiation of 3--300 mGy/year, doses from incorporated radionuclides of 12-40 mGy/year and up to 350 mGy/day (for the root vole) from Rn and Tn gases, which is substantially higher than the background ("normal") radiation doses. Biochemical, histological, physiological, morphological and population changes have been noted in plants and animals inhabiting an environment with elevated radiation background. Important changes have been demonstrated in different organs and tissues of animals exposed to high dose burdens (particularly in such radiosensitive systems as hemopoietic organs, gonads and liver).

At the same time, it has been experimentally shown that,under the effect of increased irradiation, diverse adaptive changes occur in such populations of animals and plants, with mobilization of repair capabilities of living organisms, which ultimately leads to enhancement of radioresistance on the population level. This confirmed the results of earlier radioecological studies which were indicative of increased radioresistance of higher plant populations exposed to long-term radiation under experimental conditions [16].

A study of the genetic nature of enhancement of radioresistance of populations of living organisms constantly exposed to long-term radiation (on the example of chlorella) revealed that growth of radioresistance is also associated with increased resistance of these populations to other exogenous factors [17].

In assessing the status of the problem of biological effects of low doses of radiation, it should be noted, however, that, in spite of advances in the study of this question, many basic aspects have still not been sufficiently investigated. There must be investigation of the implications of the observed changes in populations and biogeocenoses under the effect of low doses to preservation of integrity and viability of the ecosystems themselves, determination of threshold levels of permissible radiation burdens for different natural biogeocenosis with identification of critical components, as well as more detailed description of radiation and postradiation effects in biogeocenoses.

Different types of natural biogeocenoses are notable for wide variability of radiosensitivity. It is of considerable interest to investigate the radiation and postradiation effects in the least radioresistant types of biogeocenoses, which are the most vulnerable targets of the natural environment for ionizing radiations. Forest biogeocenoses (primarily conifers) are such least radioresistant ecological systems on the vegatation ground cover of our planet. The exceptionally high radiosensitivity of coniferous biogeocenoses prompted a special large-scale experiment in our country on acute irradiation of a pine and birch forest, where the source of radiation is ^{137}Cs with the following characteristics: quantity of radionuclide 32 kCi (1184 TBq), dose rate 70 R/h (5.02 μA/kg) at a distance of 10 m. The purpose of this experiment was to make a comprehensive assessment of radiation and postradiation effects in a forest ecosystem [18]. To date, two sessions of acute irradiation were effected, in the fall and spring. Radiosensitivity of the pine component to spring irradiation was found to be 2-2.7 times higher than with irradiation in the dormant phase (autumn), if death of trees is used as a criterion of radiation effects. Various cytogenetic, biochemical and physiological changes have been described in the tree layer [circle] from irradiation [19]. It was determined that the minimal LD_{100} for a pine forest is about 20 Gy [20]. For young pine forest stands, the dosage should be even lower. These data are important to evaluation of natural biogeocenotic resources with regard to possible radiation burdens on the environment. As it applies to forest biogeocenoses, analysis of reactions to radiation is also interesting from the standpoint of the fact that the many years of tree formation and very large area of tree phytomass exposed to radionuclides in the air cause formation of relatively larger absorbed doses in the tree layer, as compared to phytocenoses of other types on the ground. The study of patterns of migration of radionuclides in forests, with construction of appropriate time and space models of circulation, constitutes an independent task for forest radioecology [21, 22].

It is only very recently that radioecology accumulated experimental data on chronic effects of ionizing radiation, which permit the undertaking of attempts to describe the radioecological structure of the entire range of dose rates of ionizing radiation known and accessible to man. The following zones of chronic irradiation have been proposed [23, 24]: 1) tentative sub-background zone of possible shortage of ionizing radiation--under 0.0001 Gy/year; 2) background zone, or zone of radiation uneventfulness [" welfare"] (with subzone for man of up to 0.0017 Gy/year), up to 0.005 Gy/year; 3) suprabackground zone of physiological masking up to 0.0365 Gy/year; 4) zone of ecological masking up to 3.65 Gy/year, within which physiological changes develop into injury to some specimens of radiosensitive species and even extinction of some species, but ecosystems as a whole continue to maintain their integrity; 5) above 3.65 Gy/year is the zone of ecological damage, ranging from elimination of such mass-scale and dominant, but most radiosensitive species, as conifers in terrestrial biogeocenoses or crustaceans and fish in marine ones. It should be stressed that, on the one hand, the boundaries between these zones are based on international recommendations or generalizations of major scientists, with the exception of the purely arbitrary boundary between background and sub-background zones and, on the other hand, they should be viewed as being subject to constant correction as new data are accumulated in the fugure. Some recent international conferences--"Methodology for Evaluating the Effects of Radioactivity on Marine Organisms" [25], "Radiation Effects in Marine Organisms" [26], and others--are indicative of the increasing attention given to the study of radioecological sequelae.

Radionuclides migrating in the soil-plant-animal-diet chain are an important source of additional irradiation of man, which are ingested with foodstuffs. The contribution of this source, according to the data of the UN SCEAR [27], could constitute 30 to 60% of all additional irradiation (the rest being referable to external radiation), for various radiological situations related to release of radionuclides into the environment. The significance of this channel of radionuclide migration into the biosphere determines the urgency of problems of agricultural radioecology, which studies the patterns of migration of radioactive substances over agricultural chains and searches, when necessary, for the means of lowering the intensity of such migration of radionuclides. On the basis of the abundant experience in studying the behavior in the agricultural sphere of ^{90}Sr, ^{137}Cs, ^{131}I, ^{95}Zr+^{95}Nb, ^{103,106}Ru, ^{141,144}Ce and other radioactive fission products, modern agricultural radioecology is investigating the migration of ^{3}H, ^{14}C, ^{129}I, transuranium nuclides. The urgency of these problems is also related to the fact that most nuclear electric power plants of our country have been erected and are being constructed in the European part of the USSR, which are regions of intensive agricultural production, and this makes it imperative to have a scientifically validated assessment of radiological consequences, including migration of radionuclides over agricultural chains.

Development of ecological standards of maximum permissible concentrations of radionuclides in living organisms in the environment constitutes a most important task for applied radioecology. The principle of ecological standards for levels of radioactive substances in plants and animals is complementary (additional) to the radiation hygiene principle of restricting radionuclide concentrations in man. The need for ecological standards, in addition to radiation hygiene standards, is attributable to the fact that in most real radiological situations, other conditions being equal, living organisms receive a larger absorbed dose than man.

The validity of the last thesis can be illustrated with a number of examples. Thus, with fallout of a fresh mixture of radioactive fission products, a 1 R dose of γ-radiation in an open area (258 μC/kg) would correspond to absorbed doses in critical organs of grassy plants that are 10-50 (in extreme cases 100-250) times higher (to 1-2.5 Gy) [28]. In a coniferous forest biogeocenosis, on which γ-emitting nuclides settle, according to only absorbed dose of γ-radiation after fallout of radioactive aerosols this parameter at an altitude of 1 m (which is tantamount to the radiation hygiene criterion of permissible external γ-irradiation of man) could be 2-2.5 times lower for tree vegetation, the foundation of forest ecosystems, than the absorbed dose in the crowns of trees, which determines radiation damage to the forest [29]. If there are β-emitters in the fallout of a mixture of radionuclides, which do not play any appreciable role in external irradiation of man but which are of first and foremost significance to the radiation effects on plants, there could be a 20-fold or greater difference between doses absorbed by a man in the forest and the trees themselves [21].

An analogous drop of radiation doses is demonstrable in the chain of deep-water invertebrates-fish-man; the benthonic population receives, in addition to incorporated radionuclides in tissues, considerable doses directly from bottom deposits, whereas man absorbs radionuclides from the last link of the food chain, in the course of which their concentration in tissues was reduced by discrimination mechanisms, whereas radiation from the bottom of the sea does not, of course, reach man.

The existence of mechanisms of increased (and sometimes very high) concentration of radionuclides in plants and animals, as compared to accumulation of radioactive substances in man, in ecologically "hot" regions is another important argument in favor of consideration of radioecological criteria in setting standards for radiation factors to which environmental objects and man are exposed. Regions of the Extreme North are a vivid example of such radioecologically "hot" spots. In these regions, there is accumulation of high concentrations of radioactive substances in deer because of their consumption of lichen, which is an exceptionally efficient concentrator of radionuclides that settle from the air (due to large area of phytomass exposed to fallout and slow growth of lichen, and elimination of absorbed radionuclides from them). As a result of this, the radiation dose to deer bone tissue from ^{90}Sr settling from the air could be up to 100 times higher than in man [30].

One can use the concept of "radiological capacity of the environment," which refers to the maximum permissible amount of a radionuclide in a specific ecosystem (biogeocenosis), with which the deleterious effect of radiation on critical components of this ecosystem is ruled out, can be used as an additional quantitative criterion, with which it is expedient to impose restrictions on radiation effects on biogeocenoses and their constituents [31]. Development of theory of radiation damage to a biogeocenosis and classification of ecological changes associated with irradiation of the biogeocenosis, with distinct differentiation between permissible and inadmissible ecological changes on the population and biogeocenotic levels, constitutes a pressing task for modern radioecology in the area of development of ecological criteria and standards for permissible radiation factors.

In the natural environment, the effect of ionizing radiation is usually combined with the influence of other anthropogenic (chemical, thermal, etc.) factors, which could cause a change in radiation effects. The combined effect of ionizing radiation and other factors, which modify the radiation effect, constitutes an important branch of modern radiobiology. But, while abundant facts have been accumulated by radiobiology on the molecular, cellular and organismic levels about the modifying effects of various agents on radiation effects, assessment of the combined effect of ionizing radiation and other ecological factors on the population and biogeocenotic levels is still at its first stage. Radioecological experiments in the water coolers of nuclear electric power plants (studies made concurrently of the influence of presence in the water environment of radionuclides, thermal heat combined with the effects of chemicals and possible mechanical injury to hydrobionts) can be mentioned as an example of experimental research on the combined effect of radiation and other environmental agents [32]. The urgency of this problem in radioecology is obvious, bearing in mind that in real situations natural biogeocenoses will be exposed simultaneously to an entire set of artificial anthropogenic factors, in addition to ionizing radiation. Special attention should ge given to the combined effect of ionizing radiation and various toxic chemicals.

An important trend in development of modern radioecology is to solve problems of effects on the environment of enterprises involved in the complete energy cycle based on nuclear power for concrete technological operations, specific types of energy reactors and types of radioactive waste. Thus, radioecology of breeder reactors, reactors with pressurized water, thermonuclear power, etc., is being conceived, i.e., we can refer to the appearance of "technological radioecology," which analyzes concurrently the radioecological aspects of effects on the environment that are specific to these concrete technological operations, on the one hand, and consideration of possibility of reducing discharge of radionuclides into the natural environment by introducing appropriate restrictions and standards for dumping waste in these technologies, on the other hand.

Modern radioecology is a rather differentiated branch of science. On the one hand, it is in close contact with ecological branches of science, which deal with problems of environmental protection in this period of scientific and technological revolution. The methodology of radioecology, which is based on precise quantitative evaluation of the ecological factor (ionizing radiation) and strict determination of reactions of natural biogeocenoses and their different components to radiation (plotting dose-effect curves), is a good example for assessing the influence on the environment of other anthropogenic factors (chemical, thermal, etc.), where quantitative determination of the involved agent is not yet being made as precisely as in radioecology.

On the other hand, radioecology borders on a set of scientific medical disciplines, first of all, radiation hygiene [33]. Radioecological information about the patterns of radionuclide migration in the environment over transfer chains that lead to man are used by radiation hygiene to estimate intake of radionuclides by man, radiation doses to man and, accordingly, evaluation of radiological sequelae. Investigation of the consequences of radioactive fallout after nuclear tests, analysis of radiation conditions in man's environment and determination of the resultant exposure of man to radiation within specific regions, countries and on a global scale [34] constituted a convincing example of the fruitful collaboration of radioecologists and specialists in radiation hygiene.

In our country, research in radioecology is being pursued on a broad front, covering all directions of this branch of science. Large scientic teams of radioecologists have been formed within 20-25 years in Moscow, Leningrad, Sverdlovsk, Sevastopol, Syktyvkar and other cities. In the area of terrestrial radioecology, extensive studies of migration of radionuclides from global fallout (primarily ^{90}Sr and ^{137}Cs) in different natural environments (near-earth layer of air, soil, vegetation cover) have been conducted at the Institute of Experimental Meteorology of the Goskomgidromet [State Hydrometeorological Commission] and Institute of Geochemistry and Analytical Chemistry imeni V. I. Vernadskiy. A complex multiyear program of investigation of migration of natural radionuclides in natural biogeocenoses and effects of high natural radiation background is being implemented at the Institute of Biology, Komi Branch of the USSR Academy of Sciences. Radioecological studies on agricultural radioecology, directed toward analysis of patterns of circulation of radionuclides in the area of agricultural production, are being pursued at institutions under the USSR Ministry of Agriculture, ministries of agriculture of Union republics and the All-Union Academy of Agricultural Sciences imeni Lenin (Agrophysics Institute, Republic Radiobiological Laboratory, Georgian Ministry of Agriculture, Institute of Soil Science and Agrochemistry of the Belorussian Ministry of Agriculture). Problems are being solved successfully that are on the borderline between the interests of radioecology and radiation hygiene, dealing with patterns of transport of radionuclides over ecological chains to the human body (Institute . Biophysics, USSR Ministry of Health, and Leningrad Institute of Radiation Hygiene, RSFSR Ministry of Health). Problems of behavior of radiologically significant nuclides in soil and their migration into plants are being studied in the Laboratory of Radioecology in the Soil Science Faculty of Moscow State University.

The studies of the Laboratory of Radiation Ecology of the Institute of Plant and Animal Ecology, at the Ural Research Center of the USSR Academy of Sciences, which has received a new biophysics station in the region of the Beloyarsk Nuclear Electric Power Plant imeni I. V. Kurchatov, integrate problems of land and fresh-water radioecology into a single complex, which was named continental radioecology [35]. Comparative radioecological studies of lakes in Lithuanian SSR, in Kurshenay Bay and the Baltic Sea are being conducted in accordance with a unified plan by a radioecological team of scientists from the Institute of Botany, Lithuanian Academy of Sciences. Radioecology of river systems is being developed, on the example of the Dnepr and Danube Rivers, in the Laboratory of Radioecology of the Institute of Hydrobiology, Ukrainian Academy of Sciences; the combined effect of thermal and petroleum pollution on radiation damage to fish is being studied at the Institute of Zoology, Azerbaijan Academy of Sciences, while radioecology of fish is being investigated in the Radiobiology Laboratory of the All-Union Scientific Research Institute of Sea Fisheries and Oceanography.

The Scientific Council, "Radiobiology," under the USSR Academy of Sciences plays an important coordinating role in organizing combined scientific research in radioecology, whereas this applies to the Council for Agricultural Radiology under the Presidium of the All-Union Academy of Agricultural Sciences imeni Lenin in the area of agricultural radioecology.

In this period of intensification of use of radionuclides, sources of ionizing radiation and radiation engineering in different sectors of the national economy, as well as the intensive development of atomic energy in our country and abroad, the general task for radioecology consists of solving problems of radiation safety of man's environment and reliable radiation protection of the earth's biological resources.

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HUMAN FACTORS

HUMAN FACTOR IN CONTROL SYSTEMS

Moscow CHELOVECHESKIY FAKTOR V SISTEMAKH UPRAVLENIYA (NOVOYE V ZHIZNI, NAUKE, TEKHNIKE: SERIYA "MATEMATIKA, KIBERNETIKA") in Russian No 9, Sep 74 (signed to press 16 Aug 74) pp 1-62

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[Text] This pamphlet deals with functional distinctions of the "human" element in automated control systems. It also discusses operator training by means of a so-called algorithmic model of a control system and evaluation of efficiency of automated systems.

Introduction

Use of computers is increasing with each year in our country, in the areas of planning, control and data processing. The industrial base for electronic computer technology and other means of gathering, storing and processing data, as well as communications, is being deployed. Series production of third-generation computers has been set up, and they have become the foundation for technical, software and organizational-methodological unity of a wide range of automated systems. The unified computer system of socialist nations makes it possible to purposefully build up the capabilities of the stock of computers and to augment significantly productivity and efficiency of computer technology. A wide program of work has been started with regard to development of automated control systems to be used for different purposes.

However, there are still considerable resources for effective use of computers in planning, control and information services. A wise choice is not always being made of the problems to be solved by computers. The tendency toward "overautomation" has not yet been eradicated; this refers to the desire to relegate to automated control systems (ACS) virtually all planning, control and monitoring tasks. Not infrequently, attempts are made to leap into the future with ACS, not enough consideration is given to human factors and psychological aspects of control.

Automation of control with the help of computers is a new form of organizing ongoing [operative] intellectual processing of large arrays of information, which emerged because of the needs of the present scientific and technological revolution.

Use of computers in control is directed toward solving the following main problems. In the first place, improvement of administrative leadership and monitoring as a result of greater objectivity and better validation of decisions made by man, due to operational consideration of a considerably larger array of data in preparing for decisions. In the second place, improvement of quality and immediacy of transmitting information required to prepare and make decisions. In the third place, achievement of better quality and coordination of plans, economic and industrial technological processes. In the fourth place, improvement of efficiency of control of systems operating on a real time scale. Finally, in the fifth place, automation of calculations, engineering estimates, greater accuracy in formulating control tasks by means of their formalization and thereby providing for the highest forms of organization of mental work in general.

We can distinguish the following main classes of automated systems that use computers:

1. Large systems for transmission and processing of data (information) of the territorial type. These systems are developed in order to improve economic leadership, administrative management on a national scale for sectors of the national economy, major economic regions, All-Union and republic-level industrial associations.

2. Automated enterprise control systems (AECS) are systems for gathering, relaying and processing planning-economic and accounting data at enterprises. In such systems, solution of informational planning, accounting and monitoring problems with use of computers is combined with automated preparation of data for solving management [control] problems.

3. Automated systems of information services in public health and education, scientific research and scientific technical information, in transportation, etc.

4. Automated control systems for technological processes, which are systems that optimize modes of continuous production, control of power systems, air traffic, dispatching, etc.

5. Automated control systems for moving objects with active participation of a human operator, for example, in transportation equipment. The LEM [lunar excursion module] control system could serve as an example of such systems.

All of the above systems can be logically divided into two types. The first is referable to data processing systems (DPS). Here, the computer emerges as a tool, a means of preparing decisions made by man. The first three classes of systems are of this type. The second type refers to actual ACS, where the computer not only prepares decisions, but participates in elaborating the optimum decision. Although decision making and approval remain essentially as man's prerogative here too, he plays the role of observer and monitor [checker]. The fourth and fifth classes of systems are of this type.

ACS for technological processes or moving objects can be interpreted as machine-man-machine systems. It is expressly such systems that we shall be discussing. Here, man is included in the control process, which can proceed under simple or normal conditions, under his observation and control. The ACS operator makes decisions in accident and unforeseeable situations.

At the present time, high demands are made of the equipment of such systems, but there are equally high requirements of man, and he should be viewed not simply as a special "human" element in the overall control system (as was the case at the early stages of development of cybernetic technology), but as the principal, central intellectual element personifying the "mind" of the system.

In spite of their intensive and brilliant development, computers per se cannot generate the entire intellectual potential needed to prepare, make and implement decisions in automated systems. As it was now learned, this goal can be reached in complicated situations only if one succeeds in providing adequate flexibility of interaction between man and computer, that depends little on programs predetermined ahead of time. Such organization of interaction, although it is unusual, is a realistic and effective means of uniting the intellectual capabilities of people, enhancing their creativity.

In recent years, there have been substantial changes in the opinions of developers of control systems about man. At the present time, there is no need to advertise man as the "magic black box," capable of restoring operation of a system in case of malfunction of its elements and finding the correct decisions in unexpected situations. Questions as to the necessity of using man in control systems are a matter of the past. The opposite is truer at present: the capabilities of computers are now being questioned. The attitude toward computers in control systems at the present time is undergoing four stages, for different situations and different tasks, which are, in the words of one specialist as follows: "No, no, no!" "Ha, ha, ha!" "Yes, yes, yes!" "Oh-ho-ho!"

We are deeply convinced that the last stage could only be achieved by means of optimum [wise] organization of interaction between man and machine. Different aspects of this problem are discussed in this pamphlet.

§ 1. Distinctions of Human Performance in Control Systems

Automated control systems, regardless of their type or purpose, can be conceived of as complexes of equipment for gathering, receiving, transmitting and processing information. Man is contained as the central, deciding element in these complexes, which form the control circuit. Traditionally called an operator, he, so to speak, connects to himself the data processes in the system, operates with the data furnished to him and solves control problems. In general, the operation of such systems could be described as the successive performance of three main tasks: 1) gathering information about the controlled system and transmission thereof over communication channels, this being so-called informative information, and converting it for input in a computer; 2) processing information about the controlled system in accordance with algorithms developed in advance, which are run as programs on the computer; 3) output of controlling information, translation and transmission thereof to the controlled system.

Of course, the degree of the operator's participation in various systems varies. Some systems could theoretically operate without an operator in the control circuit (Figure 1a). Man merely starts the system, specifies the operating program and checks that it is correctly implemented. In the event of malfunctions in the system, the control process stops until this malfunction is eliminated by man. Such systems are usually called automatic, and they include, for example, systems of automatic control of technological processes in the chemical or metallurgic industry.

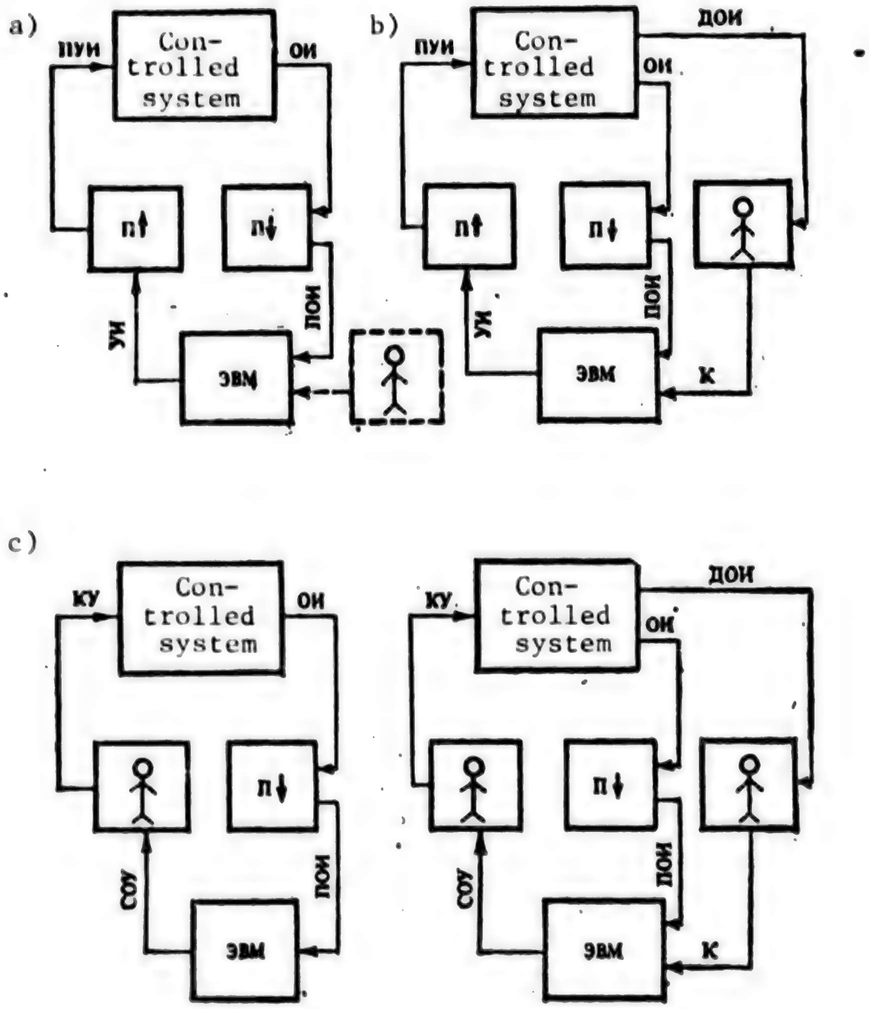

Figure 1. Circuits of control systems on different levels of automation

ОИ) notifying information
ПОИ) converted reported information
УИ) controlling information
ПУИ) converted controlling information
ДОИ) additional notifying information

П↑,П↓) information converters
СОУ) state of controlled system
К) correction of control
КУ) control commands
ЭВМ) computer

The control circuit illustrated in Figure 1b is typical of systems with a high level of automation. These highly automated control systems are sometimes called semiautomatic, which is not a fortunate term. Man is connected in parallel to the system, and part of the information about the controlled system is processed by him. In essence, the operator performs monitoring functions and, if an unforeseen situation arises, he can correct the control process without stopping system operation. The control system for spacecraft flights or LEM excursions are examples of such a system.

In actually automated systems (Figure 1c and d), man is directly and constantly involved in the control process. The operator receives information from the computer about the status of the controlled system, evaluates it, works out and makes a decision, issues control commands. There are two possible instances.

In the first, the computer puts out to the operator an aggregate of processed and ordered data about the controlled system, man evaluates this information and makes the decision as to what the system must do. In the second case, the computer puts out several variants of a decision or recommendations to man about acting on the system, having first assessed the notifying information according to predetermined criteria. In this case, the operator makes the final decision. Diverse systems of dispatcher control are of this type.

In automated systems that operate on a real time scale, where a delayed decision, even if it is correct, is tantamount to error, rather high requirements are imposed on capabilities and professional skills of operators.

The operator uses his knowledge, experience, elaborated procedures for decision making and skills in the course of informational preparation for a decision, evaluation and choice among alternatives (actual decision making) and in implementing his decision, which are essentially the principal stages of operator work. Expressly these components make up the professional image of the operator, his psychological internal, as engineering psychologists put it, means or tools. On the basis of internal resources, there is formation of operative graphic and conceptual means (models) of solving control problems. Of course, the internal, psychological means of performance are subject to special shaping and training, which has an appreciable influence on efficiency of performance.

In operational work, man also utilizes external, technical devices or tools of work, which are created by the designers of the systems. External tools include, first of all, devices for displaying information (screens, panels, mnemonics, indicator instruments) and informational (symbolic) models of control processes, controls and communication equipment executed with these devices. The computer with its software can also be considered an external tool of operator work. Analysis of the tools shows that it is important for external and internal means, primarily conceptual and symbolic models, to be coordinated, for determination and utilization of the psychophysiological and intellectual capabilities of the operator with regard to reception and processing of information and decision making.

In many instances, the operator deals with preprocessed information put out by the computer on display equipment. Various types of symbolic models and diverse display equipment are used. Expressly they provide for dynamic [operational] intellectual processing of information, dynamic creativity.

We can distinguish four types of operator work. The first is where the operator-technologist is directly included in the technological process; he works mainly in the immediate servicing mode, performs primarily controlling actions and is governed by instructions, which usually contain virtually the entire set of situations and decisions. These are operators of technological processes on automatic lines, operators who receive and transmit information, etc.

The second type is referable to the operator-observer, monitor [checker], for example the tracking operator at a radar station, dispatcher in a transportation system, etc. He already has a large share of symbolic [informational] and conceptual models and procedures for decision making, and accordingly somewhat reduced control skills (as compared to the first type). He can work in the mode of deferred servicing, and expressly such work is typical for operators of most automated systems.

The third type--researcher operator--makes considerably more use of intellectual actions and knowhow contained in conceptual models. For him, controlling equipment [controls] play an even smaller part; conversely, the share of symbolic models increases substantially. Researchers in any field can serve as examples of such an operator: those who use computer systems, decoders of various objects (patterns), etc.

The fourth type--administrator-operator--basically differs little from the preceding type; however, for him the mechanisms of intellectual activity play the prime role. This applies to organizers, administrators, individuals who make important decisions and have intuition, knowledge and experience.

Perhaps the proposed typology of operator work is incomplete (it would be expedient to single out the work of an operator-manipulator who controls robots, arms, amplifiers of human muscular energy). However, the above classification makes it easier to demonstrate the specifics of operator work and clarify the approaches to organization of wise interaction between man and computers in many systems.

§ 2. Distribution of Functions Between Man and Machine

At the present time, in spite of the seemingly broad recognition of the importance of problems of distribution of functions between an operator and automation equipment, effective methods have not yet been found to solve them. Apparently, there are quite a few reasons why optimum distribution of functions has not yet become a real source for improving the efficiency of man-machine systems.

In the first place, the tendency toward "overautomation" is still having an effect; it was so typical of the cybernetic boom in the early 1960's--the tendency to eject man from the control circuit, which was based on some exaggeration of the capabilities of automatic equipment and, as a consequence, underestimation of the capacity for self-organization and adaptive behavior of the man-computer complex.

In the second place, there is continuation of the process of occurrence of new situations and tasks for which man is not too well adapted or, at any rate, for which the real capabilities of man have not been defined. In general, not very much is known about the processes whereby man solves operational problems, particularly about processing of nondigital information and organization of active adaptive behavior.

In the third place, the stages are not always correctly chosen for development and build-up of functions of automated systems, which define the order of advancement to higher levels of automation.

What should distribution of functions mean? First of all, it is the definition of operations (and actions) that should be performed by man or machine to provide for the required efficiency of the system. In essence there are two possible variants of distribution: 1) man performs operations of monitoring the machine process of problem solving and approval of the solution [decision] and 2) the solution process cannot take place without involving human and machine operations. The first variant is a sort of parallel organization of man-machine interaction and the second, successive, step-by-step organization of interaction.

Of course, there must be validation of the choice of either variant of distribution of functions (and different versions thereof). Such validation is a difficult task. It should include both general methodological considerations dealing with man's social function as the subject of labor and practical considerations, as well as recommendations of science of control, particularly those pertaining to organization of control on the higher levels of control systems. Engineering psychology assessments and use of the results of studies of man's mental functions should occupy an important place in such validation. It is also apparent that, at the present stage, validation of wise or even optimum distribution of functions must be based on quantitative evaluation of the quality of human (and machine) problem solving and assessment of the influence of this quality on overall efficiency of the system. Although the criteria for such evaluations are far from developed, this cannot by any means serve as justification for the disregard for quantitative ratings and modeling of operations (and actions) performed by man, which is still encountered. Finally, one should not avoid the pragmatic rule, "what is done well should be done the same way," in validating some variant of distribution of functions.

P. Fitz was the first to raise the problem of distribution of functions between man and machine in 1951, on the basis of comparing their advantages and flaws. The well-known "Fitz List" spells out the comparative advantages and flaws of man and machine in performing certain basic functions. N. Jordan summarized its contents as follows: "People are flexible, but one cannot rely on them when successive performance of operations is required, whereas one can count on machines for successive [systematic] work, but they are not flexible at all. One could state it simply and, apparently, tritely: people do well what machines do poorly, while machines do well what people do poorly. People and machines are not comparable, they are mutually supplementary" [1]. N. Jordan arrives at the conclusion that one should view these two elements as mutually supplementary, rather than competing with one another.

It is common knowledge that absolutely reliable machines do not exist; any machine can malfunction. In cases where machine malfunction could lead to dangerous consequences, the system should be developed in such a way that man could manually "help" the machine. True, in this case, the work cannot be performed as well, but still it is performed. J. Glenn's flight aboard the Mercury spacecraft is a good example of this. Because of malfunction of the automatic re-entry system, the craft could not have returned to earth if man were not aboard. The problem of responsibility is another problem of compatibility of man and machine, which is acquiring increasing significance as the complexity of systems increases. Even if we were to assume that machine reliability is rather high and there is complete certainty that it will perform the task assigned to it, it is apparent that one cannot make the machine responsible for performance of the task. Responsibility can only be assigned to man. This circumstance makes it necessary to consider two things when developing systems: exact determination of the degree of responsibility of each person involved in operation of the system; providing people with the means of effective monitoring of the process and solving problems for which they are responsible.

The skeptical attitude toward different lists of advantages and limitations of man and machine is attributable to a number of circumstances, one of which is that any lists of limitations pertaining to machines run the risk of becoming obsolete even before they are published. Nevertheless, the authors could not resist the temptation of submitting a somewhat updated list of comparative characteristics, separately for man, computers and man-machine systems (see Table).

Analysis of the Fitz lists, which continue to be published, indicates that there is a turn from unbiased, almost abstract description of properties or distinctive traits of man (or machine) to validated defense of certain principles of automation that give priority to man. For example, in a special issue of the journal, ERGONOMICS (No 3, 1972) dealing with the work of operators at traffic control centers (TCC) of systems to control air traffic, the conception of man "armed" with a computer is defended.

Although some authors recognize the existence of some conservatism in man in assessing highly probable situations or with change in plan of actions, key tasks of analysis and evaluation of alternative actions must be performed expressly by him. At present, the crux of the problem consists of wise organization of "storage" of evaluations and actions that makes use of both machine and human forms and methods.

For TCC controllers ("classical" ACS operators), rapid screening of information referable to a concrete immediate task is presently of extremely great importance. Under present-day extremely complicated conditions under which they work, such screening and all preparatory data processing can be done only with computers.

We realize that the methods of qualitative evaluation based on Fitz lists have substantial flaws. As validly observed by many authors (P. Shlayen, V. Kolochkov and others), such lists are too general and do not take into consideration variability of either the machine or man, or of means of interaction between them. They do not consider the limitations and economic, social factors or human motivation; finally, they are not very strictly or significantly based on the existing (but still utterly inadequate) timing and precision parameters of operations performed by man.

Comparative characteristics of man, computers and man-machine systems

Man	Computer	Man + computer
Capable of working in unexpected (unpredictable) situations; great flexibility and adaptability to chaning external factors; can work on many programs.	Virtually impossible to program all eventualities Relative inflexibility, complexity and high cost of multiprogram work.	In unexpected situations man comes to the help of the computer, assessing the situation as a whole, combining corrective programs, guiding process on a more expedient route consistent with situation.
Can make use of insufficient (incomplete) information and form an integral idea about different events.	This capacity is very minimal and related to extreme complexity of system structure and programming.	Man defines some criteria, checks computer answers in dialogue mode, corrects them on the basis of evaluation of situation as a whole; system structure is simpler.
Wide possibilities for choosing means of action; can rapidly use reserves and correct mistakes.	Such capacities limited. Program determined by input data, little choice. Programming means of action often limited to storage and rapid action.	In some cases choice of means of action relegated to man and implementation of chosen means, to the computer.
Limited "carrying capacity" (amount of information processed per unit time).	Very high carrying capacity [throughput].	Computer prepares results, processes all data. Man processes end results necessary to control process as a whole.
Performs computing operations relatively slowly and inaccurately.	Very rapid action and high precision.	All computing operations done by computer, man is not involved in them.
Decline of work capacity due to fatigue, distracted attention, effect of emotional factors and other causes.	Steady work capacity at set level of reliability.	Decline of work capacity has a lesser influence, since the computer "insures" man. If man does not intervene, the computer makes a decision in accordance with the given algorithm and in case of gross human error blocks man's decision.

When efforts are made to use quantitative methods for validating the distribution of functions, the main difficulties arise not so much because of insufficient development of formal optimization procedures as because of the virtual absence of data about some important parameters of the man-machine system at the early designing stages, which is expressly the time when one should solve the problem of distribution of functions. For expressly this reason we should discuss wise ["rational"] rather than optimal distribution of functions.

At present it is apparent that progress in solving the problem of distribution of functions can be made only by combining qualitative and quantitative evaluations (with prevalence of the latter). Such combination should, of course, be based on a clearcut classification of the problems to be solved and ranking of their elements, primarily the concrete operations, performance of which makes up the solving process. In the general case, all tasks can be divided into five groups in an automated control system: 1) conversion of information; 2) decision making; 3) monitoring operation; 4) documentation and operator training; 5) changes in system operating modes. These tasks are subject to analysis and differentiation of their elements.

It is expedient to single out, as proposed by V. I. Kolochkov, the following elements (moving from the general to the particular): general task (one of the five listed above)--particular [special] or elementary task (subtask)--stage of subtask solving or block of operations--main (basis) operations--"hidden" level operations (on the psychological or psychophysiological level). Evaluation of reliability, timing and accuracy characteristics can be determined experimentally, on the basis of the subtasks or operation blocks and, occasionally, basic operations, and then used to create mathematical models, from which conclusions can be derived, for example, by methods of queuing theory.

It is expressly after determination of the order in which operators will perform functions (subtasks, operation blocks, main operations, etc.) and of at least the general reliability, timing and precision requirements of operator performance as a whole that one can provide validated answers to the main questions of developers of man-machine systems: how much and what kind of qualifications do operators need to solve system problems and expressly which functions they should perform; which algorithms and programs for computers must be developed; what equipment should be designed or taken from existing systems.

The next step, which actually "shapes" the chosen variant of distribution of functions, consists of determining the following: 1) final (for a given stage of designing) composition of operators, their functional duties and algorithms of their work; 2) composition of collective and individual data display equipment, work places and control consoles; 3) lay-out of display fields and controls at work places and arrangement of work places in operational rooms.

It is tempting to use several other qualitative considerations, in addition to those indicated above, particularly in man-computer systems. Perhaps these considerations were best presented by V. M. Glushkov et al. [2].

The following must be borne in mind when speaking of factors that determine the effectiveness of interaction between man and computer.

There are tasks that arise daily and hourly, which it is either inefficient or virtually impossible to perform manually. Digital computers are used for them. Investigation of the possibilities of automating decision processes is being pursued in two directions. The first, the "historical" one, is related to the process of extending automation of data processing to an increasing number of areas of human endeavor. The second line is related to the depth of such automation and reflects its theoretical capabilities, which are determined by the achieved level of formalization of different processes, as well as economic expediency of automation. The main conclusion that we can draw by combining these two lines of reasoning consists of the following: with the exception of automated control systems, man's involvement in man-computer systems is temporary. At first glance, this conclusion is optimistic for the proponents of complete automation. However, in reality, the number of problems that can be solved by an automated system, a man-computer system, is much greater than the number of problems whose solution can be completely automated. New, unformalized problems can only be formalized with the creative participation of man.

Moreover, the successful solution of most problems, whether they are problems of control, investigation or design, is impossible without man's participation in the solving process proper. It is only man's creative thinking and intuition, enhanced by such a powerful means of information processing as a computer, that can yield the desired results. It should also be stressed that we should be dealing with genuinely joint work of man and machine, with informational communication between them.

As shown in the Table, man and machine mutually supplement one another with regard to their capabilities. In order to provide for informational communication between man and computer, it is necessary to take into consideration the differences in their ability to exchange information. Furthermore, in his every day life man uses speech, written text, sketches and hands to point in different directions or places, and uses other gesticulation to relay information. The situation is substantially different in interaction with a computer. The problem of converting man's reactions (decisions) into signals that can be received by a computer and particularly the problem of adjusting the logic of the machine that would permit recognition of the meaning of received signals have not yet been totally solved by far, and this imposes certain limitations on direct interaction between man and computer.

The basic difference between human language and computer language is the most substantial obstacle to communication between them. At the present time, much work is being done in the direction of organizing communication between man and computer on the basis of a natural human or close to human language.

The term "language," is generally construed as a system of symbolic expression of thoughts and concepts that has a specific vocabulary and grammatical structure and serves as a means of communication between people, between man and automatic equipment, between various automatic devices.

There are several types of languages of communication between man and computers.

Special languages are used for direct contact between a computer as a technical device, by means of which man communicates with the computer in the dialogue mode. This includes commands or inquiries, which man uses to input his reports, to set the reading mode for some additional programs or computer devices or other, to retrieve and output needed information, correct his reports stored in the computer, etc.

A special language that reflects the specifics of a concrete system is used in the course of problem solving on a computer for communication between different specialists or operators. The languages of concrete sciences, professional jargons, computer system languages that describe the means of problem solving, etc., can serve as examples.

Finally, a distinction is made of the computer's internal language, in which the problems to be solved, i.e., the entire set of working programs, are stored in the computer's memory.

Work is in progress on developing a language of plans that would be rather close to the "natural language" of human planning so that man could, when necessary, report his plan to the computer.

The process of automatic (artificial) translation from one language to another turned out not to be as simple as it had first appeared. Difficulties arose chiefly because of the vagueness of natural language.

At the present time, the man-machine translator has been found to be more promising. Here, the computer prepares an interlinear translation (with alternatives for some words and expression, some fragments of the original text, etc.), while a man, who is a specialist in the branch of science to which the translated text belongs, finalizes this interlinear translation, rendering it meaningful and eliminating absurd expressions.

Of course, there are different types, levels and structures of interaction between man and computer in different systems. In systems of immediate [operational] data processing--ACS for technological processes, for example--the share of the machine component and, accordingly, degree of automation are higher than in systems for control of organizations or information service systems. In some systems, man performs both routine operations (coding, input of data) and operations that include intellectual evaluations. In systems with more developed forms of organization of interaction, man performs the functions of observation and monitoring, analysis of situations and evaluation of results of computer work. Man-machine dialogue is the most effective form of interaction for many tasks. This is a distinctive variant of distribution of functions between man and machine, which makes the fullest use of the capabilities of both man and computer. In principle, man-computer dialogue can be viewed as a means of protecting the system against the influence of the subjective factor and insufficiently validated decisions. But of greater importance is the fact that, in a dialogue, the machine is monitored by a stronger and more flexible intelligence.

The man-computer dialogue mode makes it possible to overcome a number of difficulties that arise in the course of operation of modern complicated systems [3].

when the computer solved ordinary mathematical problems referable to the scientific and engineering fields, there was printout of an enormous quantity of numbers that exceeded substantially the needed information. This is due to the fact that man is unable to pinpoint in advance the range of results of interest to him, i.e., he cannot monitor the course of the answer and he programs the printout of results over a wide range. In the dialogue mode, certain intermediate results are printed out and, after analyzing them, man directs the subsequent calculations by the computer.

The dialogue mode is also necessary to the process of refining modern, complicated program complexes. It is virtually impossible to run all variants of operation of complicated programs when making adjustments, nor is it expedient. In the dialogue process, the programmer soon "senses" erroneous sections of the program and eradicates mistakes, and this improves substantially the efficiency of this time-consuming process.

The man-computer dialogue mode acquires much importance in solving complicated national economic problems of planning, such as balance problems. Such problems include a long list of manufactured products (tens of thousands of names), complex correlations between quantity of produced and consumed products, presence of vagueness related to the needs for a specific product, manpower resources, etc. One of the methods of solving this problem (the static model of Leont'yev) is difficult to use in practice, since it requires an enormous amount of computer time, which leads to long intervals between calculations of different discrepancies. Specialists who correct the national economic plan then lose the general correlations, the overall picture, as a result of which the desired effect is not obtained and computer technology cannot be used to solve these problems well. It is a different matter when each suggestion of specialists familiar with local functions are implemented immediately thanks to the use of special digital methods of linear algebra (for example, within 10-20 min). In this case, the knowhow and accurate economic intuition of specialists could lead to a solution of an optimizational balance problem in the dialogue mode with a computer for a foreseeable number of iterative cycles. Man's dialogue with an information system in some tasks of automated control of enterprises is the controlling principle of such systems.

For example, it is necessary to make dynamic decisions related to use of additional capacities, intensification of a process, etc., in order to fulfill a plan within the specified time. Any of these decisions usually leads to expenditure of additional funds, and it is theoretically impossible to determine in advance which route is best in a concrete situation. The enterprise administrator, who implements management in the dialogue mode with the information system, selects intermediate criteria, defining them each time by means of feedback.

The man-machine dialogue mode is quite effective in solving an entire class of problems of pattern recognition in automation of designing, since such problems will be solved better and faster by man for a longer time than by a computer.

Thus, in dialogue systems the computer provides for accumulation and storage of data, retrieval thereof, formation and display, and it emerges as the informant, consultant, adviser and, in some cases, as a "creative" executor, for example, when there are no rigid criteria and use is made of prior experience approved by man. However, selection and formulation of a problem, choice of criteria for solving it and the ability of man's intelligence to promptly alter them if necessary, flexible interpretation and evaluation of data formed by the computer expressly in connection with the problem to be solved--all this determines man's leading role, the dominant function of his intelligence.

Achievement of mutual understanding between man and computer is the most important problem in their interaction.

These conditions, as they apply to a man-computer system, impose very definite demands on both man and machine. In this system man must [2] be able to formulate the problem quite distinctly; he must have at least general information about computers and their capacities; he should know at least one of the programming languages that the computer understands; he must be able to compose a grammatically correct description of the means of solving the problem in this language; he must know how to compare the result to the expected one and, if necessary, eliminate an inconsistency by altering the problem solving method.

As for the computer, the following requirements are imposed on it: large store of knowledge and diverse information (constants, programs of solved problems, etc.) suitable for direct rapid and convenient use in the initial program; it should understand the input languages of high level programming; it must provide a rapid and adequate answer to the consumer's question; it must have the capacity for self-organization of the computing process, as well as learning in the course of operation.

V. M. Glushkov et al. call the above set of requirements computer intelligence, by analogy to human intellectual traits such as erudition, comprehension, sharpness [resourcefulness], productivity and organization.

Let us mention that the higher the level of machine "intelligence," the less difficulties man experiences when using it to solve some concrete problem. In turn, this enables him to formulate and solve increasingly complex problems, which again makes it necessary to further develop the computer's intelligence, etc. In other words, we observe here a typical dialectical process of development of computer intelligence in the direction of approaching human intelligence [2].

The process of achieving mutual understanding can also be viewed as a process of man's study of the machine's capabilities when using it to solve some problem. As a result of such investigation, man should formulate his messages in such a way that the computer would perform expressly the actions that he expects of it. If the machine's reaction is adequate, one should consider that it followed instructions contained in man's message well and that mutual understanding was achieved in this cycle of interaction. Hence, there is a need for a special subsystem within the computer for the purpose of training the man working with the machine. And this subsystem is intended for more than an individual who is using a computer for the first time to solve a problem.

It emerges as an inalienable part of the man-computer system also when the user of the machine is rather highly trained. In such cases, the subsystem has the function of accelerating mutual understanding between man and computer, which is achieved by means of forming in it knowledge about the capabilities of the machine, composition and functions of the library of standard programs, solved problems and distinctions of the input programming language, which the user has either forgotten or overlooked, etc.

Learning as the basis of mutual understanding also has another aspect--teaching the computer, which consists of adapting the machine to man, its comprehension of the meaning of his messages, self-organization of the computing process. Achievement of mutual understanding of man and machine is a dynamic process of mutual training, in the course of which man must first adapt to the level of machine understanding, then gradually raise it to his level, in part by defining and explaining his messages and in part by using its capacity for learning, recognition and generalization.

Meeting the requirement of convenient communication between man and computer implies implementation of both general and special requirements of ergonomics and engineering psychology with regard to convenience of lay-out and construction of equipment for input, output, as well as visibility of inputted and outputted messages, etc.

As indicated by Liklayder, as far back as 1960, one of the main problems of organizing interaction is to eliminate the dependence on previously defined programs, which deprive this interaction of flexibility. The same problem determines the main specifications for indicator equipment (outputs) and controls (inputs) involved in interaction. The scheme of interaction is illustrated in Figure 2.

The terminal indicator devices, which consist of a screen and console (it is convenient to call them videoterminals, or videoterminal devices; sometimes they are called screen consoles) have presently found numerous diverse applications and realizations of interaction on different levels. As can be seen in Figure 2, interaction occurs between the part of man, in which information is processed, i.e., the brain, and the part of the computer, in which information is also processed, i.e., its main part, which consists of a central processor, main memory [storage] unit and operating system. The videoterminal device in itself merely intensifies or accelerates interaction between man and machine, since one cannot consider the transmission of data in either direction--from computer to man or man to computer--completed until the conjugation signals are analyzed and until the human brain that processes the information or computer's processor makes a decision concerning their significance.

Since these devices serve as the main channel for transmission of information from the machine to man and from man to the machine, expressly their technical parameters could become the weak point in the ever expanding programs of man-computer interaction.

The results of analysis of the problem of distribution of functions, with due consideration of the latest advances in electronic computer technology, offer convincing confirmation of the fact that man is still the most important element in both present and future control systems. Successful reproduction of some thinking functions by means of machines cannot serve as grounds for unconditional elimination of man from the control process. Of course, there is no limit to development of technological progress, including computer modeling of human functions. However, advances in the area of modeling mental processes will always follow development of the capacities of man himself (A. N. Leont'yev).

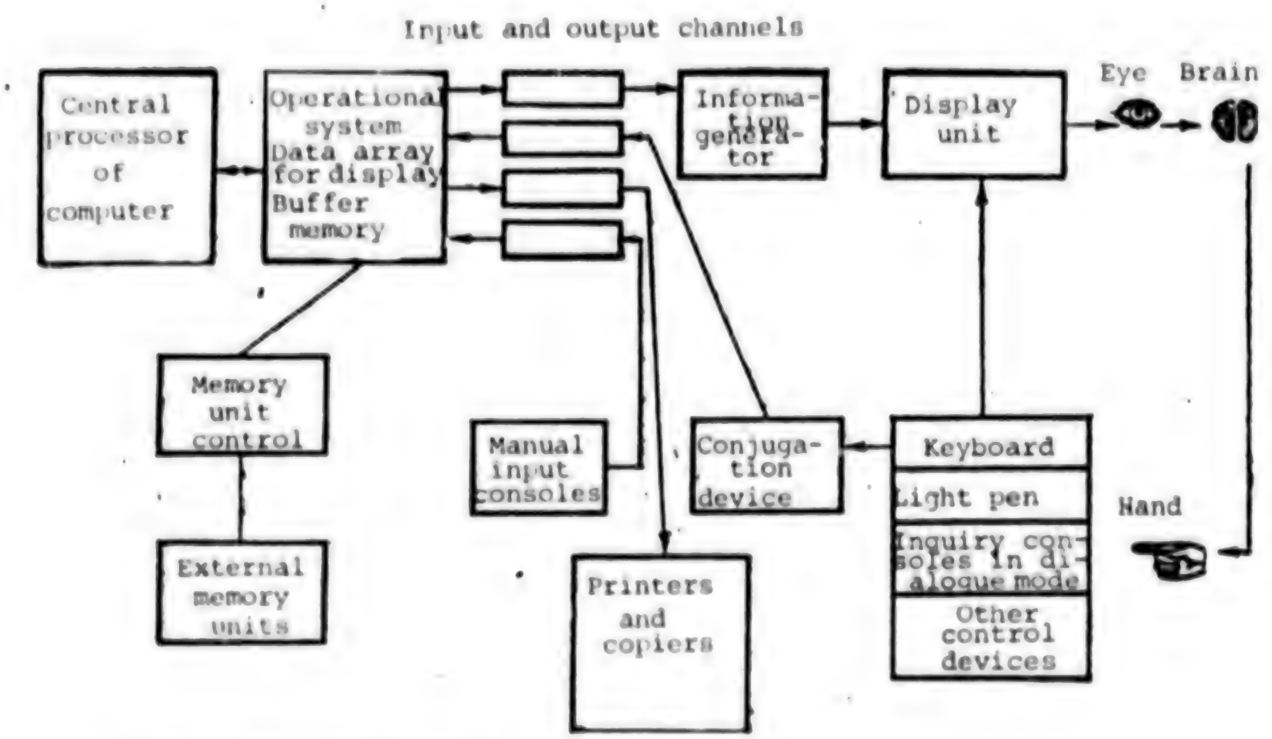

Figure 2. Diagram of man-computer interaction

§ 3. Display of Information in Control Systems

One of the distinctions of work of a system operator is that he cannot observe the controlled systems directly and is compelled to use information that he receives via communication channels. Thus, the operator interacts with a symbolic [information] model, i.e., a simulator that retains all of the properties of the real system that are important from the standpoint of control tasks.

The symbolic model consists of the aggregate of information about the state and operation of systems involved in interaction and the environment, which is organized in accordance with a specific system of rules and presented to the operator by means of display devices. In order to define the specifications for display systems, let us consider the system operator's work with information models.

One can conceive of the process of displaying system operation in the form of several abstract levels. The levels differ in degree of details about the displayed process. The lower level is the system of detailed display of all information about the state of controlled systems, environment and control process. The top level provides an abstract idea about system operation on the dichotomy principle (operates "poorly," operates "well").

A man working with an abstract information model is compelled to refer to more detailed information to interpret the real situation. When there is detailed display of all of the information, man is compelled to select the needed information, process and obtain generalizing information characterizing a given situation.

In both instances, the operator's activity is not productive. His capacities are limited by the information display system.

It is rather difficult to actually define unequivocally the degree of details in a display system. However, there is apparently a range of optimum display of the process of system operation for any concrete system, which covers several average levels of detailing. Let us arbitrarily call the top level in this range the integral information model of system operation and the bottom level the detailed information model.

In order to define the specifications for information models, one should take into consideration the fact that an objectively problematic situation displayed by the model should be promptly detectable by an operator. Hence, the fewer conversions or requests for additional detailed information needed by the operator to reduce it to a form that is consistent with operational tasks, the more precise and efficient the operator's work.

In modern automated systems, the display of the control process depends very largely on the tasks that a concrete system performs. Still, we can outline some trends, consideration of which in developing systems improves substantially the effectiveness of display and the process of system control: a) provisions for rapid conversions of traditional information models (text, tables, symbolic and formular presentation, graphic analogue models) and greater flexibility and operationality thereof; for this purpose, it must be possible to order the displayed data upon instruction from the operator and to manipulate with the information model (take data from the display, request additional data, alter format, make shifts over the screen or panel, underline, single out, mark, input data from other sources). In this manner, the following could be effected: input of hypotheses (forecast) for different variants of solutions, definition of hypotheses, input of various restrictions and bans with consideration of priority of messages, correction and control of flow of information to operator work places and display units. b) improved efficiency in using information models by improving their psychophysiological characteristics, for example, use of special signals attracting the operators' attention to situations that require their immediate intervention, check-back signals to verify and assess the results of operator work, multidimensional stereoscopic (pseudostereoscopic) and integral information models with a high degree of generalization of information; c) refinement and expansion of use of graphic information models that furnish a graphic idea about generalized estimated data and rapid comparative evaluation thereof, improved display of dynamic parameters of a situation; d) refinement and greater descriptiveness of information models intended for displaying modes of operation and states of controlled systems and the system as a whole, data referable to functional monitoring and checking readiness, broad use of mnemonic principles, simplification and greater effectiveness of emergency and warning signal systems.

As a rule, there is functional (with equipment) communication between information display units and the controlling computer in large systems. For this reason, the computer could help the operator substantially by relieving him of some of the work involved in finding problem situations.

In addition, the degree of detailing information depends appreciably on the level of hierarchic control structure where the operator is located. If we are dealing, for example, with the highest element of a control system, the task of qualitative evaluation of the situation as a whole and, on this basis, making decisions that are important to the process of controlling the system as a whole are inherent in the operator.

This distinction of the highest control elements makes it necessary to use integral methods of submitting information in the information models, and for this reason we shall discuss mainly integral information models that display the course of the process of controlling a system as a whole.

The specifications for information models have been described rather comprehensively in the literature. We shall list the main ones referable to integral models: the data model should display only the properties of controlled systems and the control process that are relevant to controlling the system; it should be free of irrelevant details that distract attention; the model must be descriptive, i.e., the operator must be able to receive information rapidly and without meticulous analysis, which is particularly important when there are strict time limits; the model should make it possible to forecast the situation; the model should enable the operator to rapidly check the results of his actions; the information relayed in coded form should be comprehensible to man. The most effective coding is closely related to the possibility of rapid interpretation of information furnished to the operator; the model should be well-assembled and provide for rapid perception of a situation as a whole.

These requirements provide a good idea about the main properties of an integral data model. Let us illustrate the possibility of constructing an integral model that meets the above requirements on the example of a hypothetical control system operating on a real time scale.

The control process consists of changing the system from one state to another by acting on its parameters. The discreteness of control systems in this class is their typical feature, i.e., controlling actions are performed at discrete points in time, at a specific operating pace h that is set by the control cycle. For control cycle j let us use τ_j to designate the time spent on converting the input message into an aggregate of signals at the computer output, and we shall assume:

$$\tau_1 = \tau_2 = \tau_3 = \ldots = \tau_j = \ldots = \tau_k.$$

Hereafter we shall designate control cycles by a series of non-negative numbers, $0, 1, 2, \ldots, n, \ldots, k$, that make up the alphabet $\{t\}$. The current cycle corresponding to the present time will be designated with the letter n. Let us call the sequence of operation of logic conditions of the controlling algorithm in each jth cycle of control the trajectory for counting the jth cycle.

The state of the process in each control cycle is displayed by a counting [or reading?] trajectory, the evolution of which constitutes a certain function that reflects progress of the process of controlling the system as a whole. Let us designate as the graph of control function the reflection [display] of evolution of the counting trajectory on a certain plane.

Let us introduce logic function ω so as to have:

$$\omega = \begin{cases} 0, \text{ if } H[n] = H[n+1]; \\ \pm 1, \text{ if } H[n] \neq H[n+1], \end{cases}$$

where $H[n]$ is the counting trajectory for control cycle n, $H[n+1]$ is the counting trajectory of the next $n+1$ control cycle.

Using the ω function let us define the levels of control.

Let us use L_s to designate the set of values of control function in m control cycles ($m \geq 1$), for which $\omega = 0$.

The move to the next ($s \pm p$) control level occurs with $\omega = \pm 1$, and a positive value of ω signifies a move to a higher $s+p$ level while a negative value of ω means a move to a lower $s-p$ level ($p \geq 1$).

We believe that there are methods to determine a change in the counting trajectory and which level it belongs to in a given jth control cycle.

We now logically move on to the following graphic geometric interpretation of the control process. Let us designate as control plane the plane on whose x-axis are plotted the control cycles (n) and on whose y-axis are plotted the control levels L_s ($s = 0, 1, 2, \ldots, k$); k corresponds to the last (highest) level of control (L_e) which means that the end goal is reached. The start of the control process is set by current time t_s ($n = 0$) and the end by time t_e ($n = (t_e - t_s)/\tau$). The control process is conceived as movement of a certain abstract point in the control plane from level to level. The trajectory of this point is the graph of the control function.

Every counting trajectory referable to a specific control level is assigned a corresponding number. One can arrange the levels on the y-axis in such a manner as to have the point move for better descriptiveness in ascending order of numbers toward top level L_e. When level L_e is reached within time $t = t_e - t_s$, it means that the technological process has been fully performed, i.e., the task has been performed.

Let us use the term, integral data model of control (IDMC), to designate the control plane and chart of control function that are displayed on the indicator screen. Graphically, the control function is a step function of time in the control plane (see Figure 3).

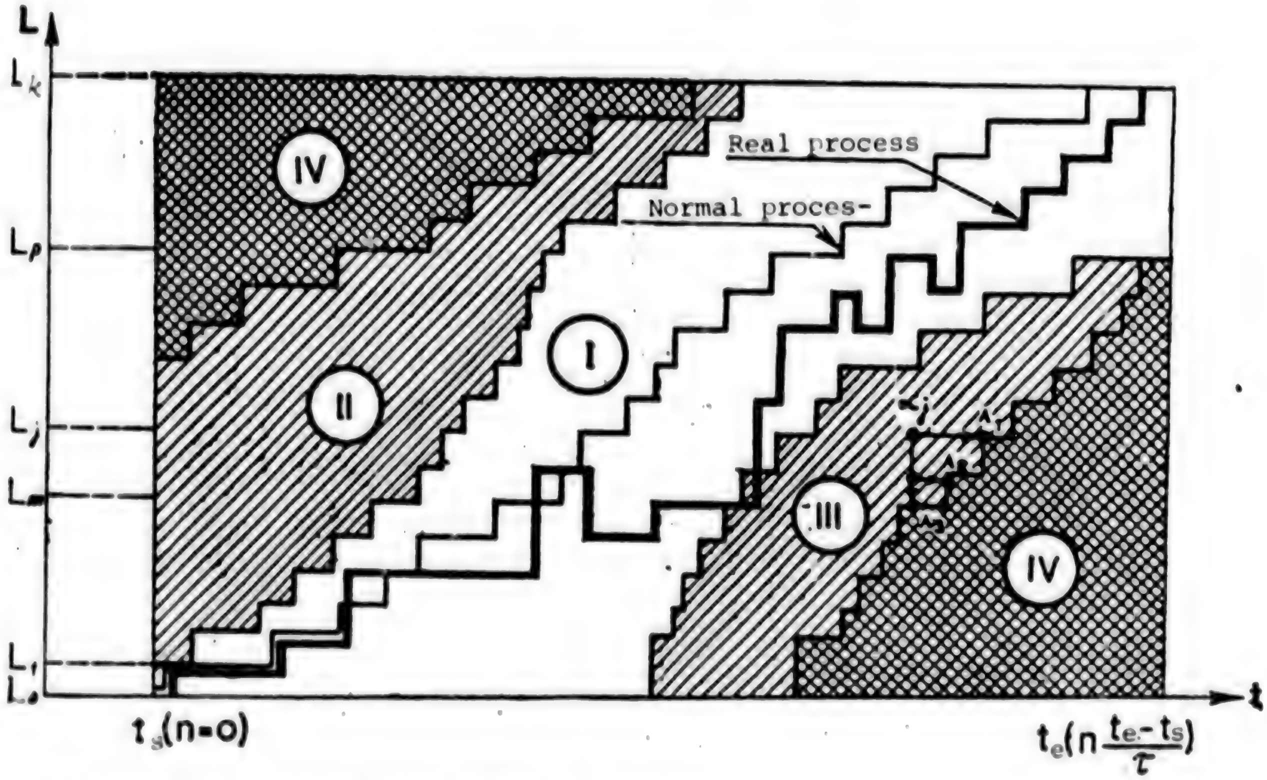

Figure 3. Integral data model of control

Let us introduce the concept of an ideal control process.

We shall call ideal a control process that meets the following conditions:

1. $\phi(n)$--ascending step function of time so that $\phi(n) \geq \phi(n-1)$.

2. The moment of change from the ith level of control to the 1+ ith level is defined as $t_{L_i} = M[t_{L_i}]$, where t_{L_i} is time spent on process on ith level, $M[t_{L_i}]$ is mathematical expectation t_{L_i}.

3. The time that the process reaches the ith level of control is defined as:

$$t^*_{L_i} = \sum_{i=1}^{i=l-1} M[t_{L_i}],$$

where $t^*_{L_i}$ is time at which ith level is reached.

4. Total duration of control process does not exceed the set time, i.e.,:

$$\sum_{i=1}^{i=k-1} M[t_{L_i}] \leq t_e - t_s$$

In actuality, the probability of an ideal control process is very low. In reality, the time of moving from one level to another has a scatter in the region of $M[t_{L_i}]$, which is determined by the appropriate law of distribution. We will call such a process normal. In order to define the normal process in the general case, we must know the distribution functions $F(t_{L_i})$ and duration of process on each level.

We shall call a control process normal when it meets the following conditions:

1. $\phi(n)$--ascending step function of time.

2. The time of change from the ith level of control to the 1+ ith level is defined as:

$$t^{+}_{L_{i+1}} = t^{\bullet}_{L_i} + \Delta t^{+}_{L_i}/F(t_{L_i}) = P(t_{L_i} < \Delta t^{+}_{L_i}) = \varepsilon_1,$$
$$t^{-}_{L_{i+1}} = t^{\bullet}_{L_i} + \Delta t^{-}_{L_i}/F(t_{L_i}) = P(\Delta t^{-}_{L_i} < t_{L_i}) = \varepsilon_2,$$

where t^*_L is time at which process reaches ith level; $\Delta t^+_{L_i}$ is maximum time of process on ith level; $t^+_{L_{i+1}}$ and $t^-_{L_{i+1}}$ is time of change to i+1 level; $\Delta t^-_{L_i}$ is minimum time of process on ith level; ε_1 and ε_2 rather high and rather low probability, respectively, of value of t_{L_i} determined from the graph of distribution function $F(t_{L_i})$.

The slant line, /, signifies "on the condition that."

3. Minimum and maximum time of reaching the ith level of control is defined as:

$$(t^{\bullet}_{L_i})^{-} = \sum_{i=1}^{i=l-1} \Delta t^{-}_{L_i}/F(t_{L_i}) = \varepsilon_2,$$

$$(t^{\bullet}_{L_i})^{+} = \sum_{i=1}^{i=l-1} \Delta t^{+}_{L_i}/F(t_{L_i}) = \varepsilon_1,$$

4. Total duration of control process does not exceed the set time of:

$$\sum_{i=1}^{i=k-1} \Delta t^{+}_{L_i}/F(t_{L_i}) = \varepsilon_1 \leq t_e - t_s$$

and as a corollary of the second and third conditions:

$$\sum_{s=1}^{s=i-1} \Delta t^{-}_{L_s}/F(t_{L_s}) = t_l \leqslant \sum_{s=1}^{s=i-1} M[t_{L_s}] \leqslant \sum_{s=1}^{s=i-1} \Delta t^{+}_{L_s}/F(t_{L_s}) = t_i.$$

The real process differs from a normal one in that the change from level to level does not necessarily occur in strict order. In addition, changes in reverse order cannot be ruled out, so that we cannot refer to one-to-one increase in function $\phi(n)$ and, finally, the values of a real control function $\phi(n)$ on the levels can exceed the range defined by the normal control process (Figure 3).

In view of the foregoing, the maximum permissible time of reaching level L_i, provided the task is performed in a real process, can be expressed as:

$$t^{*}_{L_i} - \sum_{\mu=1}^{\mu=n} \sum_{s=1}^{s=i-1} (t_{L_s})_{\mu} \leqslant t_e - t_s,$$

where t_{L_s} is the duration of the process on the sth level, μ is the number of times the process occurs on the sth level in the course of one technological cycle.

In a real process, if it does not exceed the range stipulated by the conditions for a normal process, control is effected automatically by means of an algorithm run on the computer. If the process deviates from the normal one, man makes the decision to correct the algorithm.

To construct the model we must single out the control levels that satisfy the following conditions: they are the most relevant from the standpoint of the control process; total number of levels should not be large for better descriptiveness, but sufficient for effective monitoring of the control process; the characteristic features of corresponding levels must be readily discernible on the current counting trajectory by means of the computer program.

The method of constructing the model is based on the assumption that, for any control process effected by means of a computer, one can always single out the characteristic features formed by the controlling program, which reflect the process in stages, and these features could be arranged in order of their formation as the process advances toward the end goal. Knowledge of the control process and its time diagram permit distinction of control levels on the basis of order of appearance of the corresponding notification* signals from controlled systems and formation of controlling signals on the computer.

If notification signals or other information, the content of which reflects a change in state or mode of operation of systems, proceed from controlled systems to the computer in the form of $\gamma_{01}, \gamma_{02}, \gamma_{03}, \ldots, \gamma_{0j}, \ldots, \gamma_{0n}$, this sequence is reflected in the control program of the computer as a sequence of program tags $\gamma_{p1}, \gamma_{p2}, \gamma_{p3}, \ldots, \gamma_{pm}$, and always $\underset{m}{U}\gamma_p \geqslant \underset{n}{U}\gamma_0$, since the computer program can provide for controlling actions on controlled systems, which have their own inherent tags regardless of incoming notification signals from the controlled systems.

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*Translator's note: "Notification" or "notifying" information probably refers to status and descriptive input data and the term is also used with reference to signals.

It is logical to expect that appearance of any program tag will cause a change in counting trajectory, otherwise there is no need to form a special tag. The order of control levels is determined by the order of input of signals γ_{0n} or order of formation of tags γ_{pm}, which is determined by the conditions for a normal course of the control process.

The levels of control that arise as a result of possible corrective action by the operator on the control process are situated among levels that reflect the normal course of the process consistent with the distinctions of a concrete technological process.

In practice, the following task, which is related to the control process, is often encountered. In the nth control cycle the process is on level L_i; one has to select $\phi(n)$ so that the process would move to level L_g in j cycles, i.e., to the $n+j$ control cycle. And it is usually required for the process of movement from level L_i to level L_g to be "optimum" in a certain sense.

We shall use "optimum" [best] hereafter to refer to a process that reaches the end goal within a minimum time. It may be the most expedient to have the control process move to one of the trajectories that reach level L_g by the $n+j$th control cycle by means of corrective operations provided in the control algorithm. The choice of operation, in this case, is left to man and the performance, to the computer. The task of efficient control by means of IDMC consists of prompt perception that a situation is problematic and the feasibility of corrective action for prompt correction of the process.

The IDMC reflects the progress of the control process in time, and achievement of level L_k means that the task has been performed entirely (for example, output of high-grade product); reaching level L_p corresponds to partial performance of the task (for example, product is made, but it is of poorer quality) (see Figure 3). If at least level L_p is not reached in the control process, the task is considered not to have been performed.

The operator of the system can determine when he must intervene in the process according to the position of the working point in relation to the boundaries of the zone outlined on the display on a real time scale.

Figure 3 illustrates an integral data model of a control process (IDMC) in a hypothetical system with the following regions:

I. Region of normal control process, in which control is effected by the computer program. In this region, it is possible for the system operator to correct the program for optimization purposes, but it is not mandatory.

II. Region of possible emergency situation, in which man's intervention is mandatory. Unlike region III, in this case the process occurs with an advance and cannot avoid moving into the emergency region (occasionally, it is possible to stop the process, lower the level or start the control process from the beginning). However, if the system operator does not make a decision at the right time, an irreversible process could begin, which is tantamount to moving into the emergency region.

III. Region of probable emergency [accident] situation, in which operator intervention is also mandatory, otherwise the process could move into the emergency region.

IV. Emergency region of system operation, in which any human intervention is useless, i.e., in any case the end goal will not be reached.

The levels of control and regions of interaction between man and computer can be calculated mathematically for a concrete system, on the basis of statistical data or models.

The above-mentioned regions of interaction between system operator and computer in the control process enable the operator to rapidly assess the developing situation and reach an appropriate decision.

Let us consider in greater detail the method of man's communication with a computer in the dialogue mode, which is done by means of the integral data model (IDMC) and special subprograms which permit correction of the control process (controlling program of computer) in real time systems. The following needs to be taken into consideration:

1. In any case, correction of the control process is made with some lag in relation to occurring real events. For this reason, the operator is required to make the proper decision about correcting the controlling algorithm with due consideration of the forecast from displayed ongoing events.

2. The man who corrects the control process must at least comprehend the logic of computer operation and have a clearcut idea about the result of using the corrective methods available to him.

3. The high speed of computer operation should be used to check the accuracy of a made decision. Indeed, in many instances, it is very possible to determine in advance the results of corrective action with the help of a computer. The only thing that is necessary is to make the correction in accordance with certain rules, with consideration of necessary conditions. In a number of cases, a computer operating on a given program can detect an operator error and remind him of it.

The specifications for a special corrective program ensue from the tasks that are performed by a concrete system, and they are closely related to the structure of the controlling algorithm run on the computer; the following should be considered the main requirements: simplicity and operationality [immediacy] of putting the appropriate corrective subprograms in action, which is done by decision of the system's operator; universality of the corrective program, i.e., the program should include corrective methods for a wide range of parameters of the controlling algorithm that are relevant to the process;

selectivity, i.e., there must be restrictions that permit input of only the corrective operations that are relevant to the current stage of the control process; possibility of checking with the computer the results of the correction man makes in the control algorithm. Here, by means of appropriate indicators, the computer either informs the operator about the results of his correction or blocks the decision he made, if it was made too late or leads to an emergency mode; autonomy of the corrective program, which permits input of additional corrective subprograms without appreciable adjustment of the main controlling algorithm.

Let us discuss in greater detail the selectivity and possibility of checking a decision with a computer.

Organization of the logic part of the corrective program and validated inclusion of some corrective subprograms or other must be preceded by analysis of the control process in a concrete system, with consideration of interaction between man and computer. The results of this analysis should serve as the basis for organizing the data model and distributing functions between man and the computer, i.e., the areas of possible and mandatory human intervention in control processes must be defined, and the appropriate system of notification signals developed, which would permit assessment of the state of the process at the current time. The display also shows the appropriate decision [permission] indication. The need for such information is obvious since: in the first place, the operator cannot always rapidly recall the structure of the control algorithm at a concrete stage that determines the possibility of intervention for a given situation; in the second place, the operator cannot always conceive of the process exactly in time, i.e., when it is possible to make some correction; in the third place, the decision [permission] indication could also serve as confirmation of the fact that the operator's decision was implemented on the computer, since the appropriate indication could have been removed with input of the correction.

The "permission" indication makes it possible, in a way, to abide by the selectivity principle since it concentrates the operator's attention only on the corrective methods that have a bearing to the current stage of the control process. In essence, the selectivity principle is followed automatically by means of the system of restrictions in the logic part of the corrective program.

Blocking so-called "unwise" [irrational] human decisions is of special significance in organizing communication between man and computer. As we have mentioned above, in real time systems control creates a time limit for human decision making. A delayed decision loses its effectiveness.

In the event that man is late with a decision, the latter could be made by the computer in accordance with the rules contained in the control algorithm, or it can be blocked and not received by the computer. In addition, man could make the wrong decision. In this case, if it does not lead to an emergency situation, when the operator has become convinced of the error of his actions according to check displays, he could cancel a prior decision and make the correct one. If the decision made by man could change the system to an emergency mode (monitoring is done by the computer), the latter is not received by the computer, and there is a display to inform the operator of this.

Thus, for the system operator to be able to use the system's control equipment efficiently, it is necessary to elaborate an adequate information model, corrective program and wise distribution of functions referable to the control process between man and computer.

Let us examine one of the possible means of checking man's decisions with a computer.

Let the process be on the level at point α_j (Figure 3) at a current point in time. To change the process to the area of normal operating mode, man takes the *i*th variant of correction of the controlling algorithm. This decision should satisfy at least two mandatory conditions:

1. The time required to run and obtain the proper result from the *i*th correction of the control algorithm should be shorter than the time in which the process reaches the boundary of the emergency mode region (arrowheads A_1, A_2 in Figure 3).

2. When running [accomplishing] the decision made, it is possible to switch the process to a lower control level. However, this change should not occur below level L_m, on which the process turns to an emergency mode at the current time (arrowhead A_3).

Technically, it is not difficult to implement the proposed method. In any case, when a human decision is blocked, man is notified of this through check-back indicator systems. The indicator that shows the allowable, notifying, check message, as well as information that reflects the current status of controlled systems and environment will be called the detailed data mode.

The system operator refers to the detailed data model to obtain additional information, which could be needed in the decision making process if a problem situation arises, as determined by the IDMC, as well as to determine what possibilities there are to correct the process and check his actions. Validation for using some corrective subprograms or other, elaboration of IDMC (determination of control levels, regions of interaction and relevant control parameters) and the detailed data model is preceded by special analysis of the process of controlling a concrete system, with consideration of interaction between man and computer.

As we have tried to demonstrate, display equipment holds the principal place at the present time among the devices that implement interaction between man and computer. The equipment for displaying information and consoles for data input could be called the main hardware for communication (dialogue) between man and machine. For this reason, one of the principal ways of improving the effectiveness of man-computer interaction is based on combined studies of hardware and psychological means of activity. We refer mainly to better conformity of the types, volume and forms of information presented to man to the psychophysiological and psychological characteristics of his perception, memory and thinking. Moreover, there is still much to be done to optimize conditions for man's work with machines, to develop and implement the ergonomic requirements of interaction equipment.

We should expect considerable progress in the near future in the area of methods and equipment for displaying information. There will be parallel units for display, with sufficient overlapping of information, explanation of links between elements of the displayed situation and means of precluding the possibility that the operator would skip essential, important information. There will be possibilities of readjusting [altering] (if necessary) the structure of the data model in order to facilitate the task of searching for the needed information; dynamic data models will be developed, with accumulation of data and optical display of this process. Colors will be used extensively in display equipment. There will be reliable visual monitoring of transmission of command information; wide use will be made of rapid transmission of data from some display units to others, for example from individual to group units--panoramic displays. In the more distant future, sound movies on a real time scale will be used for many systems.

A well-organized system of instruction and training is an important factor that enhances man's capabilities when working together with a computer.

§ 4. Algorithm Model as a Trainer for Control System Operators

As we know, in addition to service personnel, who observe, make preventive inspections or repair equipment, there are operators who are involved in the overall process of transmission and processing of notification information and elaboration of controlling actions, i.e., they are directly involved in the control process.

The role of operators in a complicated system varies, depending on the level of control on which they perform their duties. The operator staff of a complicated system can be arbitrarily divided into several categories, according to the operator's position in the system and his influence on the control process as a whole: operator of system as a whole, operator of controlled systems [units], operators of individual devices.

The category of an operator determines the nature of his work and difficulty of problems he solves in the control process.

Operators of individual pieces of equipment in the process of controlled system operation monitor the operation of their equipment, make appropriate corrections, adjust parameters, etc. The actions of this category of operators are defined essentially in advance by the instructions on operation of their particular device [unit, equipment].

The operators of controlled systems, for example, power units, monitor operation of the unit in the mode of centralized control. When the process deviates from the normal [nominal] mode, operators correct the operation of the units, using a self-contained system in a limited range, without disconnecting the unit from the mode of centralized control.

The system operator holds the highest rank in the hierarchic structure of control; he controls the system as a whole; all of the means of centralized control of system units are at his disposal; he can make any decision to assure achievement of the end goal by the system. The system operator must have a clearcut idea about the entire industrial process, the main task for the system, control circuit; he must know the ways and means of having the system reach its end goal; he must have the necessary rights to make a given decision and bear full responsibility for performance by the system of the task as a whole.

The requirements are relatively low for lower-rank operators; it is enough to know that normal, technically trained people with the necessary experience and work skill will service the controlled systems and different units. The units they service operate in the mode of centralized control. Their work is limited by instructions and theses prepared in advance.

The main requirement of this category of operators is rapid and accurate performance of actions as stipulated in the instructions. These actions do not usually consist of something unusual or new to the operator. However, in a problem situation, there may be a sequence of input of corrective operations that is other than provided in the instructions. Expressly the unusual nature of operator actions in a difficult situation leads to mistakes, which can be attributed to the mental state observed in some people in a situation of surprise and great responsibility for their actions. For this reason, it is necessary to investigate man's individual traits and assess his so-called operational traits as they related to a concrete control system, to provide special training under close to real conditions.

Operational traits are not simply knowledge and experience needed by the operator. This concept includes the ability to apply this knowledge and experience to the control process, i.e., a real situation.

The operational traits of lower-ranking operators are determined by their reactions, speed and accuracy of actions described in the instructions.

The operational traits of an operator on the highest rank (system operator) are determined by his operational thinking, ability to rapidly solve complicated intellectual problems.

The requirements made of higher ranking operators can be divided into three main groups.

1. The system operator must have the required aggregate of knowledge: he must have a clear idea about the task put to the system, the end goal of system operation as a whole; he must know the schedule of the industrial process, i.e., the intermediate goals that must be achieved in the course of system operation and the target dates for them; he must have an idea about possible external perturbations, effects of the environment on controlled units and system as a whole; he must know the capability of the system, i.e., the properties and characteristics of controlled units, communication system, logic of controlling algorithm operation, distinctions of the computer complex, reservation system, etc.; he must know the methods for optimizing and receiving corrections, the main variable parameters of the control process, and he must have a good idea about the results of using these methods and procedures in the process of system operation.

2. The operator of the system must have adequate work experience, which enables him to do the following: assess the developing situation, promptly realize the possible consequences of an "impending" problem situation; he should be able to quickly and correctly select the method of correction of the control process, of those at his disposal, that conforms to the reaction to the occurring situation; he should assess rather rapidly the results of his correction.

3. The system operator must have the appropriate psychophysiological qualities that enable him to perform his duties well in a difficult situation. They include the following: psychophysiological stability, which refers to the ability to maintain a specified or required level of functional state in the presence of a wide range of external influences on the operator; operational qualities, i.e., rapid generalization, precise analysis, capacity to predict (extrapolate) situations, imagination, etc.

The above-listed operator traits are obtained by learning, accumulation of proper experience and constant training on special training equipment under conditions that are close to real ones. Training results could serve as the basis for assessing the fitness of operators for controlling a concrete system, as well as for comparing operators for screening purposes. However, use of technical methods of assessing performance is not possible for all categories of operators. Apparently, we need to consider this matter in a broader, sociological aspect. Indeed, system operators are not simply executors (such as, for example, operators of individual units), but primarily they are administrators of groups, ideologists of systems (main designers, flight operation officers, chief engineers, senior dispatchers, etc.). For this reason, the screening process referable to them had already occurred primarily according to other criteria.

Nevertheless, training on special simulators is necessary for operators in any category, for them to acquire ability and skills that enhance their efficiency in real situations.

Let us examine one of the possible means of creating such a simulator on the basis of an algorithmic model of the control process.

Control algorithm is a term generally used to designate the finite aggregate of precisely formulated rules, according to which is effected the process of controlling equipment (units [systems]) in solving a class of problems put to a given system. Let us use the term, control [controlling] program (CP), to designate execution [running] of the control algorithm in the language of a concrete computer.

The process of controlling system units consists of operation of the CP. Man's role in the control process amounts to monitoring proper operation of the CP and correction thereof if there is a deviation from normal operating mode.

The speed of operation of modern computers and operation of systems on a real time scale create substantial difficulties in perception and interpretation of rapidly changing situations in the course of controlling the system's units.

On the one hand, man must be able to visually monitor the computing process on the computer, i.e., he must be able to visually monitor CP operation.

On the other hand, high requirements are imposed on man, chiefly with regard to his operational qualities. It is unquestionable that operational human traits can be enhanced appreciably by instruction and appropriate training under conditions that are close to real work.

It should also be noted that instruction and training can be successful only if the following is provided: regulation of CP operating pace (for example, slowing down in the parts of the timing chart for the control process that contain the largest number of events); visual observation of computing process at points that are relevant to the control process as a whole; stopping the CP and printing out all information required to assess a given situation; repetition of the most typical segments of the timing chart for the control process.

Of course, in the course of actual work such a mode of CP operation is impossible. However, the main properties of the CP make it possible to create a mode for CP operation with the above-listed capacities after performing real work.

The control program of a computer is a strictly determined system which reacts unequivocally to each situation formed at a specified time. In other words, any set of input data (notification information) in the CP is made to match [conform] to a certain set of output data (controlling information). The strict determination of the CP is its main distinction, upon which subsequent reasoning is based.

Another distinction of the CP is that it is immaterial to its operation whether the notification information at the input is real or simulated. It is quite sufficient for the information to be received at the specified pace, in the required time intervals and, in the case of closed circuits of control, that there be a certain conformity between informative and control data.

We shall construe as algorithmic modeling the modeling of a system's behavior as the behavior of its CP. Let us discuss the principles of designing algorithm models for one of the possible structures of a complicated system.

Figure 4 illustrates the flowchart of a system, which reflects in general form the functional relations between controlled and control systems, an element of which is a computer with a control algorithm (CP) run on it.

Considering the special position of the computer CP in the system as the central control organ, it is deemed possible to exclude the real informational links with controlled units and the environment [outside] and connect them right at the CP (Figure 5). Real notifying and control information is replaced with information recorded in the course of real work with its corresponding times (t_1, t_2, t_3). This is enough information to repeat (reproduce) CP operation in the process of real work, and this reproduction can be made on an arbitrarily chosen time scale. One can fix [record] input information in the course of real work on, for example, external computer storage units. Since identity to real system work is provided, with regard to both input information and its timing, the CP as a strictly determined cybernetic control system reproduces its behavior unambiguously (i.e., sequence and results of calculations) in real work on an arbitrarily specified time scale.

An algorithmic model can be used for teaching and training operators, and it has a number of advantages over other models and simulators, since it reproduces the control process and all elements of system operation on a real time scale.

In essence, these advantages consist of the following: the model reproduces the real picture of prior system operation on display equipment; the control process can be reproduced in both slow and fast motion; it is possible to stop the control process, have pertinent information printed out as desired by the trainee or instructor, situations can be repeated, one can back up to any time segment and continue work with retention of the actual situation; reproduction of the real control process is not related to the operation of real systems; it is not necessary to develop additional equipment; the model is based on a real CP and several additional programs in computer memory.

The process of operator training can begin with visual viewing of the control process in slow motion on a data model of the system. While viewing several prior system operations, the instructor explains to the operator the distinctions of the control process; in each cycle he points out the difficult areas of work and the most frequently encountered situations.

As knowledge and experience are acquired, the operator gradually starts to work independently on controlling the process, in slow motion at first. His task is to promptly and correctly assess a developing situation and, if the process deviates from the normal mode, adjust the appropriate parameters of the CP in order to correct the control process. As the operator acquires

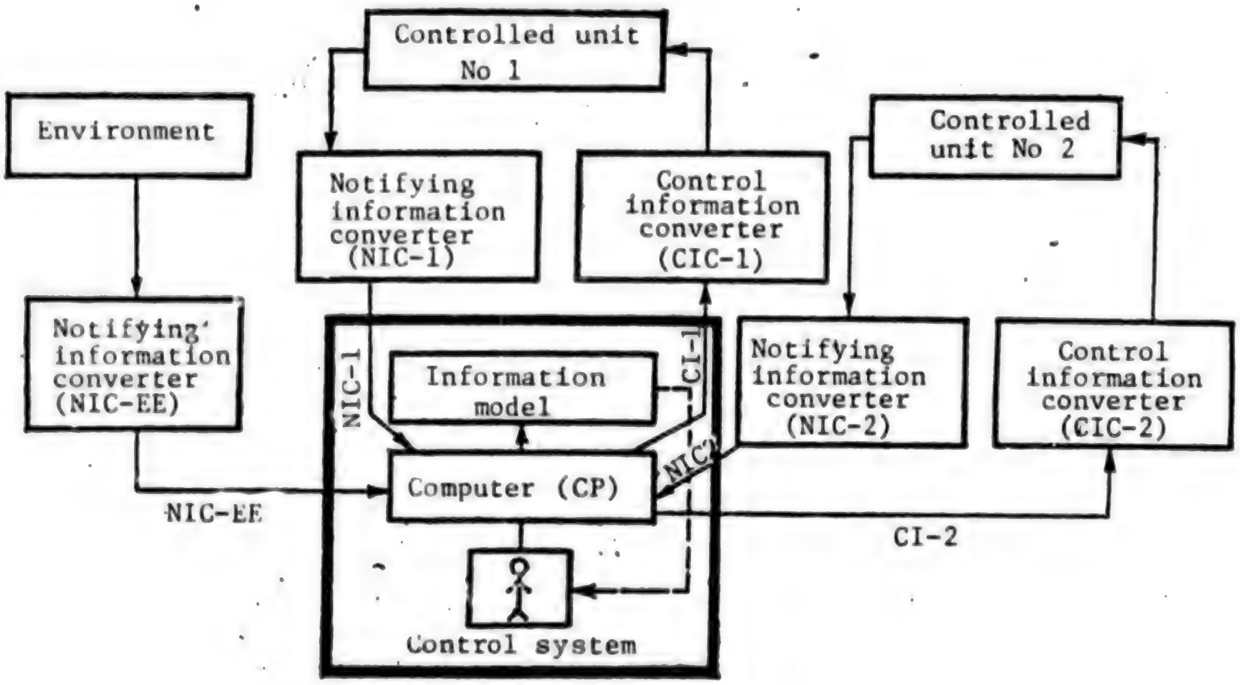
Controlled unit No 1
Environment
Controlled unit No 2
Notifying information converter (NIC-1)
Control information converter (CIC-1)
Notifying information converter (NIC-EE)
NIC-1
CI-1
Information model
Notifying information converter (NIC-2)
Control information converter (CIC-2)
NIC2
Computer (CP)
NIC-EE
CI-2
Control system

Figure 4. Flowchart of hypothetical control system

Key: EE) external environment
CI) control information
CP) control program
NI) notifying information

skill, one can speed up the CP operating pace, coming closer to the real pace. Accuracy of trainee's actions is checked by comparing the end results of prior real work to the new results of the trainee operator.

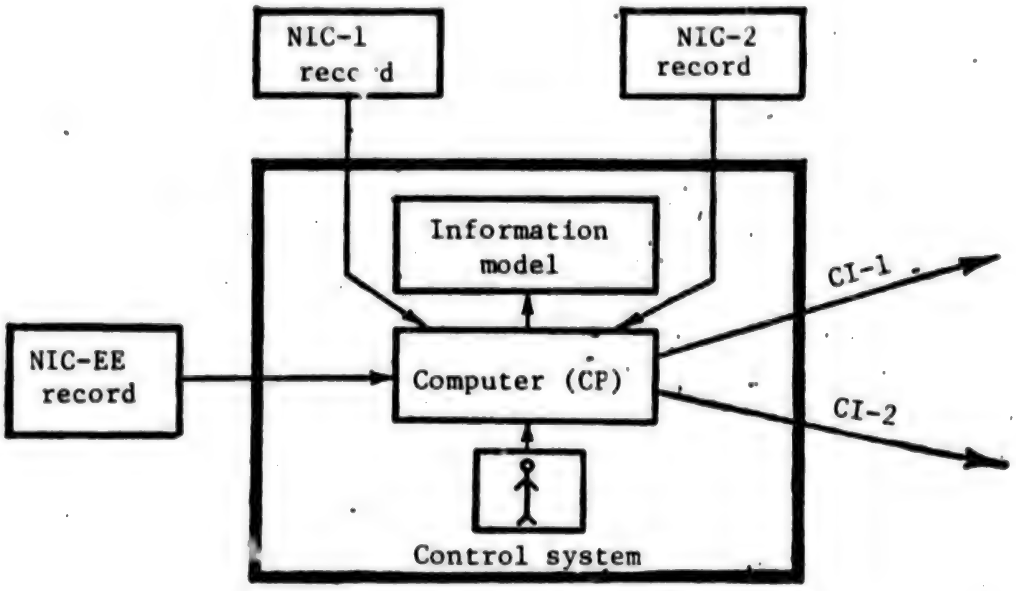

Figure 5. Flowchart of algorithmic model of control system. Key is the same as in Figure 4.

In the course of teaching and training operators, one can use not only the record of input information obtained in real work, but simulated information obtained from running special subprograms of computer memory. In this case, the situations can be given arbitrarily at the input of the control system (CP input) and made more difficult by the instructor as the operator gains skill. The instructor or a group of experienced specialists evaluate the accuracy of operator actions.

The fact that the algorithmic model can operate on a real time scale makes it possible to record operator actions in the process of control with regard to time, which permits upon subsequent analysis (after printing out all of the resultant data) determination of operator reaction time to developing situations, i.e., his operational qualities.

Thus, algorithmic models of control systems provide for a teaching and training process, serving as a universal training unit [simulator] for operators.

§ 5. Some Principles of Assessing System Efficiency

It is an important practical task to determine the efficiency of a man-machine system, which has to be done both at the system development stages and during its operation. In spite of the considerable quantity of works dealing with the problem of assessing the efficiency of complex systems, there has been poor development of principles for assessing efficiency of systems that contain a "human" element. One encounters different approaches, contradictory conceptions and various terms. Some authors try to break operator work down into elementary operations (psychophysiological acts) and quantitative assessments of the latter are viewed as elements of the rating of system efficiency. Some authors mention the exlusivity of efficiency parameters for man-machine systems, that cannot be reduced to machine, technical system parameters. Others allow for the use of slightly adjusted reliability parameters to assess system quality or, in general, prefer to speak of reliability instead of efficiency [effectiveness]. Finally, in some works, there is evaluation of factors that determine efficiency of interaction between the user and the computer [2].

Nevertheless, this situation does not appear discouraging to us. On the contrary, it should stimulate further efforts in this direction. Indeed, system efficiency is the main criterion of its expediency. System efficiency is the main factor that is considered in producing a system, updating it, comparing competition designs. Efficiency is used as the basis for forecasting the trends of scientific and technological progress, growth of labor productivity, etc. The results of assessing efficiency determine the entire set of questions related to socioeconomic conditions of automation of control as a whole.

Quite a lot of knowhow has been gained to date in the area of systems analysis. Unquestionably, the search for methods of assessing system efficiency should be pursued as it applies to the purposes and tasks of a system. It is also obvious that efficiency parameters must be chosen with consideration of a concrete task; they should be expressed in quantitative form and simple "heuristic" requirements must be met, which were already formulated in the earliest works on systems analysis and studies of operations. Apparently, the main difficulties in assessing efficiency at the early stages of developing a system are related to quantitative expression of the problem, or more precisely to transformation of the system's purpose (end function) into quantitative parameters of system tasks or elements of this task. It should be noted that such transformation is not obvious for a wide class of man-machine systems, particularly for data processing systems and organizational control systems [management systems?].

Such systems have elements of uncertainty in operation or behavior, and for this reason not all of their output parameters can be expressed quantitatively. For this reason, one often has to resort to analysis of a set of artificially determined parameters of system operation. Analysis of such a set of parameters, which is made by highly qualified experts, facilitates forecasting of system efficiency in many instances. These parameters usually include those that affect system efficiency to some extent or other.

This approach enables us to transform efficiency rating into a work tool for designing a system, since it guides the developers toward concrete consideration of factors that affect system efficiency.

We shall proceed from the definition used in systems analysis and use the term, system efficiency, to refer to the "degree of adaptation of the system to performance of given tasks under specific operating conditions."

There is a tradition of writing down the parameter of efficiency expressing this degree of adaptation in the form of a complex function:

$$Э = f(\bar{x}_1, \bar{x}_2, \ldots, \bar{x}_n),$$

where $\bar{x}$ is the vector characterizing a given output parameter of the system.

This expression facilitates formulation of the general conception, in spite of the difficulty of exact specification due to the presence of immeasurable or statistically uncontrollable variables.

When analyzing this expression, it must be borne in mind that several factors, which are not directly related to operator work, influence the system's efficiency. We can single out the following as the principal factors, which we shall call efficiency loss factors: organizational-structural factors that determine optimality of system structure and selected modes of its operation (for example, centralized, decentralized, mixed modes); presence of the necessary feedback circuits; structure of exchange of information when moving from one hierarchic level to another, etc., i.e., $\Delta Э_{str}$; poor input information (insufficient or poor order of parameters characterizing controlled system or environment, random or deliberate interference, etc.)--$\Delta Э_{in.inf}$; deficient computer algorithms for problem solving (excessive complexity and lack of economy, unwise organization of computing processes and data processing, etc.)--$\Delta Э_{alg}$; inadequate reliability of hardware (equipment for gathering, storing, processing, displaying and transmitting information)--$\Delta Э_{rel}$--and, finally, other than optimum organization and back-up of work of operators, control and service personnel--$\Delta Э_{h.f}$ [h.f--human factors].

Although each of the above loss factors is present in practice, one should not think that overall loss is excessively high. The fact of the matter is that one must take into consideration the difference in time of loss occurrence due to different factors, as well as of man's ability to correct or avert efficiency loss due to equipment malfunction, poor computer decisions [solutions], poor input information, etc. For this reason, we could write down the following expression for total loss of information:

$$\Delta Э_{\Sigma} = \sum_{ij} \Delta Э_i - \sum_{ij} \Delta Э_i \Delta Э_j + \sum_{ijk} \Delta Э_i \Delta Э_j \Delta Э_k - \ldots,$$

which is analogous to the expression for the sum of probabilities of concurrent [combined] events. It is heuristic and requires validation for each concrete system.

The next step in augmenting the accuracy of evaluation $\Delta Э\Sigma$ could be made if we succeeded in finding methods of weighing these loss factors and comparing them to one another. However, experience has shown that such weighing is feasible in rare instances; there are too many variables that would have to be taken into consideration. At the present time, such a "multilevel" problem cannot be solved for complex systems.

In order to determine the nature and structure of as yet unrealized possibilities for enhancing the efficiency of human performance in man-machine systems, it is necessary to select reference parameters of efficiency of operators referable to any specialty. Such parameters should include accuracy, operationality [immediacy of action] and reliability of performing functions assigned to operators.* The aggregate of these three characteristics of performance should serve as the basis for assessing efficiency of both people and operation of the man-machine system as a whole.

Accuracy, operationality and reliability of performance of assigned duties and operations that they consist of are the three main criteria for evaluating loss of efficiency due to the human factor--$\Delta\text{Э}_{h.f}$.

What determines the reference [base] parameters--accuracy (Δ), operationality (τ) and reliability (p) of problem solving or different operations making up the solving [or decision] process? What factors influence these parameters?

One should single out the following groups of factors: 1) structure (or algorithm) of operator work, including type and nature of performed functions, nature of distribution of functions, degree of strain [stress], means of organizing group work, etc.; 2) operating qualities of equipment used in operator work (location, construction and convenience of using equipment at work places, display equipment and controls, etc.); 3) environmental conditions--temperature and other microclimate parameters, noise, vibration, illumination, etc.; 4) mode of work (duration of shift, rest schedules, etc.); 5) level of professional training of the operator (knowledge, skills, experience, etc.); 6) individual human distinctions (psychophysiological and anthropometric characteristics, intellectual capacities, emotional and motivational stability, other psychological personality traits).

Apparently, the problem of assessing efficiency with regard to consideration of the human factor could be solved if we were able to relate or even estimate the aggregate influence of the above-listed factors on $\Delta\text{Э}_{h.f}$. However, this is extremely difficult to do.

Estimation (analytical, theoretical) methods exist only for elementary algorithms of work with certain limitations for other groups of factors. But such simple and well-defined situations are not often encountered. Methods of physical modeling, with the possibility of varying the values of variables, are more promising, and for this reason models for efficiency rating, at the output of which one can obtain quantitative values for $\Delta\text{Э}_{h.f}$, should be viewed as promising methods of analysis.

Traditional experimental methods, as well as professiographic examinations, can also offer much toward demonstrating the dependence of reference parameters (Δ, τ, p) on influential factors.

As an example, we shall illustrate calculation of system efficiency for one special case, where the operator is included in the control process upon occurrence of an emergency situation and alters the course of the process by means of corrective subprograms. The parameters used in this calculation can be obtained experimentally.

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*We wish to stress here that performance of functions assigned to operators also includes joint solution with the computer of control problems.

Let overall system efficiency, with consideration of operator performance, be written down as:

$$Э = Э^{*} + (1 - Э^{*})E,$$

where $Э^{*}$ is system efficiency without involvement of an operator in the control process; $E = C_1 \cdot C_2$ is efficiency of man-computer interaction in the control process; C_1 is probability that operator will make the correct decision in the control process; C_2 is a value that characterizes the degree to which the system has performed the task in the case where the operator switches the control process from emergency mode to the region of normal operation (see § 3).

Determination of coefficient C_1:

We shall refer to the following as operator error: the operator made the wrong decision, i.e., he interfered in control of the system when it was unnecessary, or else made a mistake in choice of corrective action; the operator made the correct decision but took longer than the permissible time, i.e., he was late in execution.

In any system ["apparatus"] of process correction, we can assume that there is a finite number of corrective actions (K_j ($j = 1, 2, 3, \ldots$), and each correction or certain combinations of corrections could be used in very definite situations $S^{i}_{K_j}$ ($i = 1, 2, 3, \ldots, p$). Situation refers to the state of the control process and system equipment that is formed in the course of the process in the moment of time under consideration. Let us call $S^{i}_{K_j}$ a special situation. The number of special situations, the reaction to which can be elaborated by means of the jth correction, is finite. Assessment of operator efficiency can be made by modeling the special situations in an entire set, defining the system's reaction to each of them, and the special situations are selected from the entire set at random. In each test, one fixes the time spent by the operator on decision making $\Delta t_1^{K_1}$ $\Delta t_2^{K_2}, \ldots, \Delta t_n^{K_j}$ and conformity of the operator's decision to the decision determined a priori for the given situation. The probability that the operator will make the correct decisions in the entire set within the permissible time is determined as the ratio of correct decisions to total number of trials [tests]:

$$C_1 = \frac{n^{*}_{K_j}}{n_{K_j}},$$

where $n^{*}_{K_j}$ is number of correct operator decisions out of entire set $\Delta t_{\nu}^{K_j} \leq t_{\max}$;

n_{K_j} is total number of trials (decisions made by operator);

$t_{\max_j}$ is time allowed to operator for making decision an input of correction K_j;

$\Delta t_{\nu}^{K_j}$ is time spent by operator on decision and input of correction K_j in the νth trial.

Determination of coefficient C_2:

Coefficient C_2 can be written down in the following form:

$$C_2 = \frac{1}{m} \sum_{i=1}^{m} S(B_i).$$

where $B_i = \frac{t_B - t_\Pi}{t_B}$ — is the coefficient that considers time to bring system out of emergency situation

t_B is the time required to bring system out of emergency mode with consideration of corrective action K_j;

t_Π is time operator spent on making decision to chose corrective action K_j and execute the chosen correction.

In practice, it is often sufficient to select t_B and t_Π to determine coefficient C_2. Of course, both of these parameters are dependent, i.e., an increase or decrease in time required to bring the system out of the emergency situation influences the accuracy or time characteristics of achieving the end goal of operation.

Having used the above expressions, the efficiency of the system can be defined as follows, with consideration of man-machine interaction:

$$Э = Э^{\bullet} + (1 - Э^{\bullet}) \frac{\dot{n}_{K_j}}{n_{K_j} \cdot m} \sum_{i=1}^{m} S(B_i).$$

Analysis of elements of $\Delta Э_{h.f}$, which is examined in the overall structure of efficiency rating, is a rather complicated and time-consuming matter. The formula for $\Delta Э_{h.f}$ is a complex function of time, accuracy and probability of unfailing (or error-free) performance of the *i*th task or operation. In performing such an analysis, it is apparently expedient to move from the "special [particular] to the general," i.e., to move from precision, time and reliability ratings of performance of different operations, subtasks and tasks to evaluation of larger units of operator work. The statement that it is wrong to simply add up these ratings remains valid.

When choosing the variables, with reference to which analysis is made of factors of loss of efficiency, one should also use a certain conceptual scheme. We use the conception of means of operator work (see § 1) as the basis of such a scheme. Thus, with regard to information models, consideration of factors affecting efficiency should include the following: conformity of the data model to methods of problem solving by the operator; choice of optimum formats and volumes of displayed information for the operator; optimum combination of integral and detailed data models; wise distribution of information over the operators' reception channels; optimum psychophysiological conditions for presenting information; optimum rate of renewal of information.

With reference to work places and controls, this consideration should include: optimum location (assembly) of display and signal zones, as well as operations fields on panels and consoles of work places; optimum distribution of controls on console operating field; wise arrangement of work places in operations rooms; adherence to all anthropological, hygienic and other ergonomic requirements to provide for comfortable operator working conditions; convenience of training and instructing operators at the work places.

In the area of operator training and organization of work, the following must be provided: clearcut classification of professional operator specialty with definition of specific requirements as to knowledge, skills and personality traits of operators; implementation (when necessary) of special psychophysiological operator screening and special operator training; optimum work modes [schedules].

Factors that produce stress--in most cases disruption of activity due to excessive psychological or psychophysiological stress--have an important effect on efficiency of a wide range of operator functions (and efficiency of the entire system) in man-machine systems. These stress-producing factors include time limits for problem solving, sensory overload or underload, psychological incompatibility of the group, extreme environmental factors, inadequate level of professional training, false motivation or set, and many others.

For the time being it has not been possible to formalize the effects of stressors in a more or less acceptable form, although some distinctions could be taken into consideration in mathematical modeling of operator performance and evaluation thereof. In particular, this could be done, for example, to determine the intensity or duration of exposure to a stressor.

In conclusion, let us mention that one should proceed in many directions to enhance the efficiency of man-machine systems (to lower $\Delta \text{Э}_{h.f}$). The main ones are: 1) optimum distribution of functions and organization of interaction between man and automation equipment, as well as between operators; 2) conformity of information and algorithm properties of machines to psychophysiological and intellectual traits of people; 3) raising the level of professional training of operators; 4) creating standards of performance that are consistent with optimum comfort of working conditions, on the basis of satisfying a set of ergonomic requirements and standards.

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